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Issue 177

"Felines spend up to 16 hours a day taking a cat nap, whereas dogs are a little more active"

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This was a marvel of medieval engineering

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Even if you've had both cats and dogs as pets, everyone tends to prefer one species at least a little bit more than the other, whether that's because you enjoy a dog's unfaltering loyalty or the fierce independence of a cat. You probably think you know the differences between the two, and their strengths and weaknesses. But unless you're a vet or a trainer, you could be very misinformed on some points. In this issue of **How It Works**, we look at the biological, psychological and evolutionary differences of the world's most popular household pets. You'll discover how different breeds have developed – physically and mentally – over thousands of years and how our own evolution has been influenced by our relationships with these animals. Enjoy!

Ben Biggs
EDITOR

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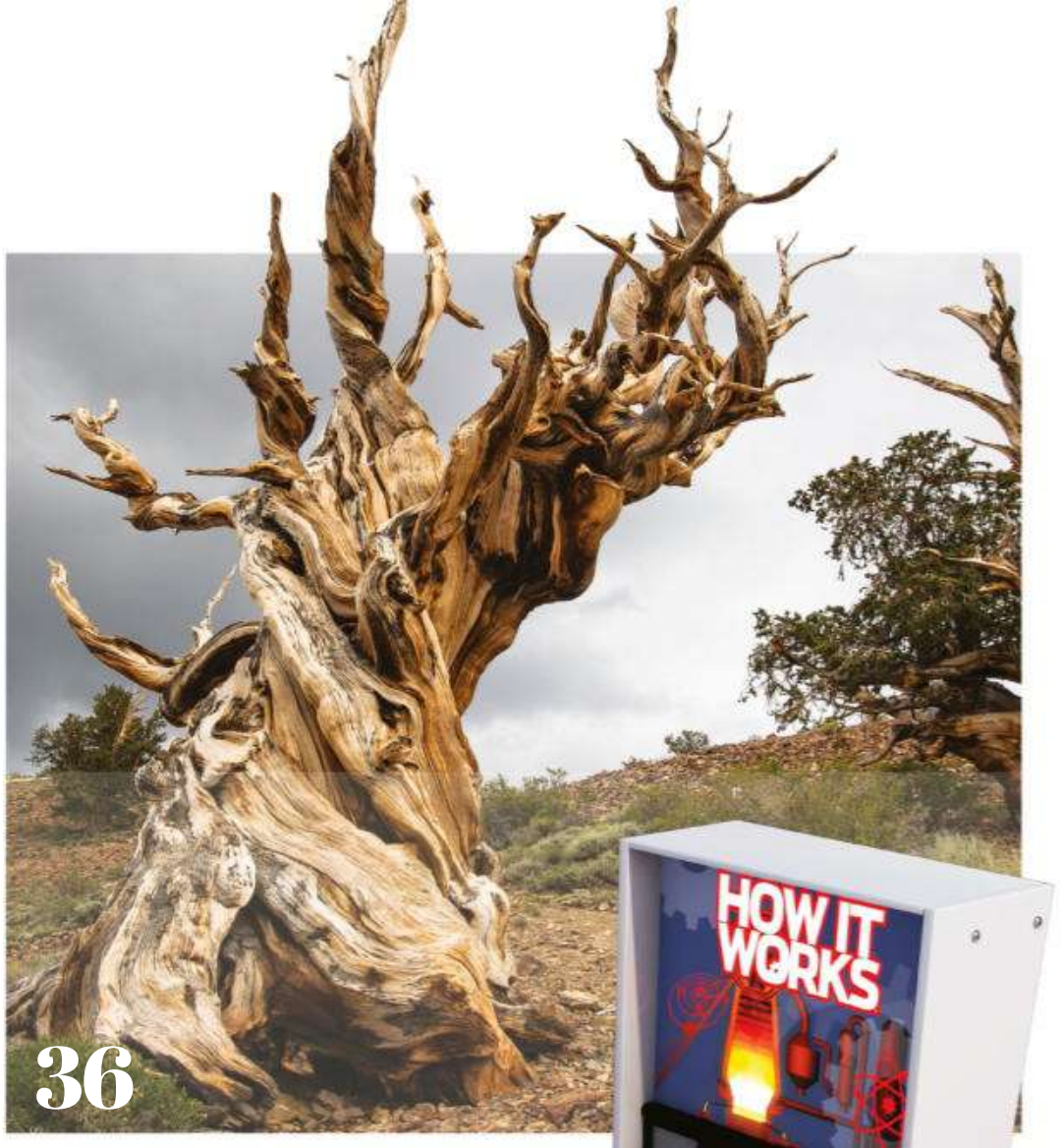

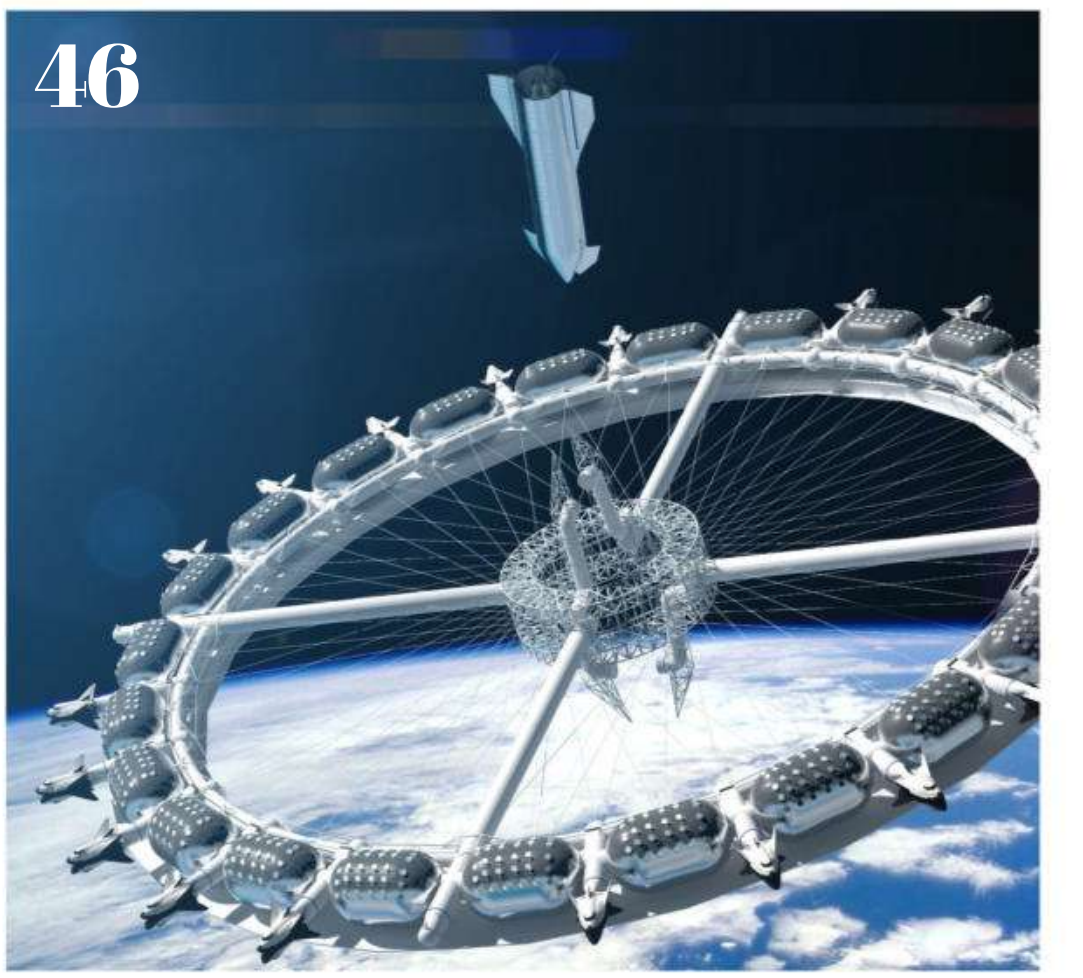

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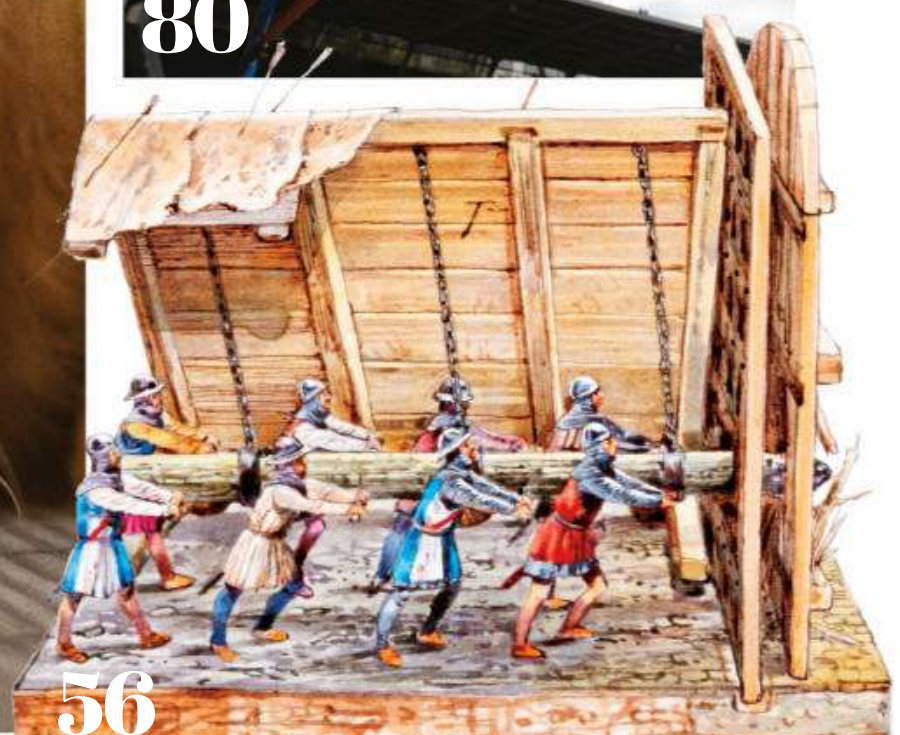

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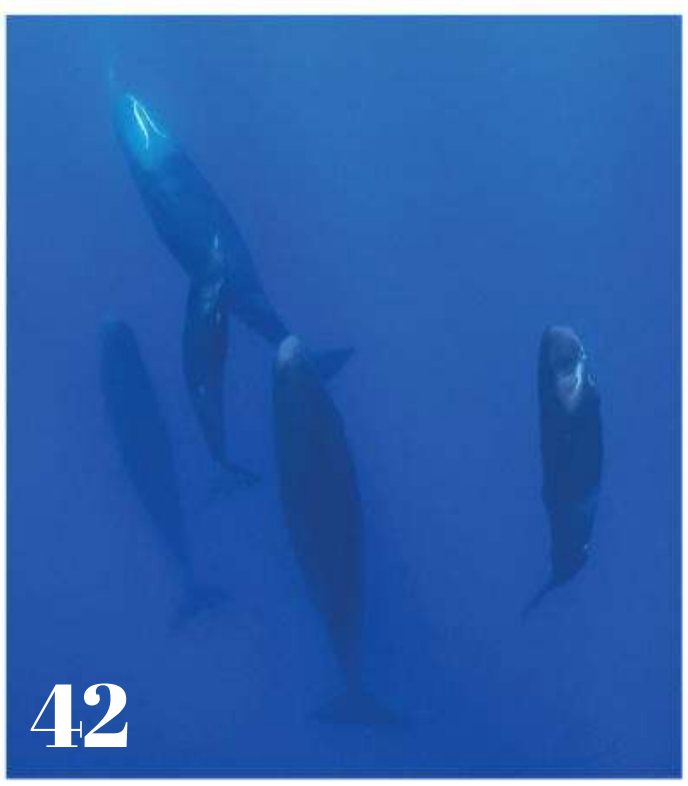

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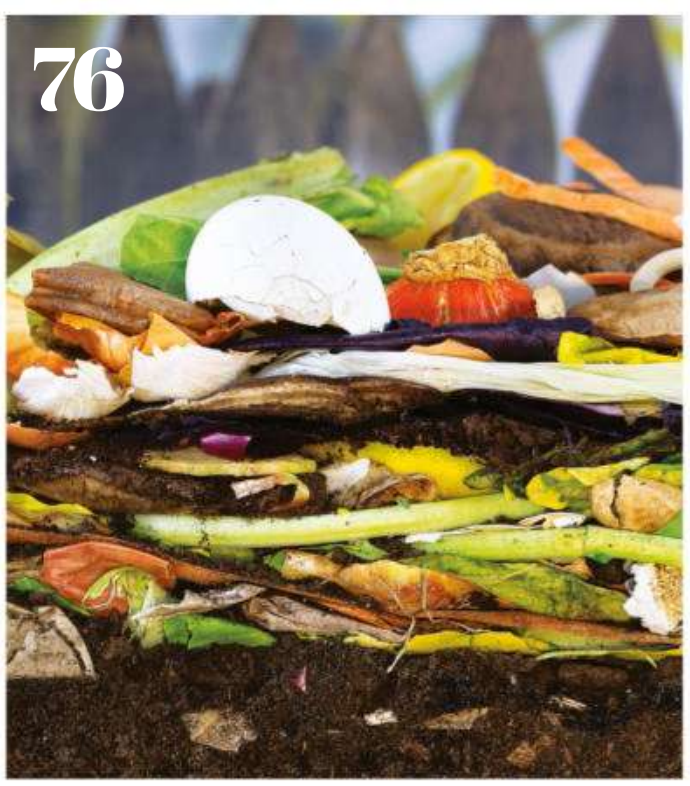

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Deploy the decoys

An American Air Force AC-13OU gunship can jettison decoy flares to evade enemy forces. When heat-seeking missiles are on the tail of gunships like this, a series of decoy flares are deployed. These are magnesium-filled tubes that burn much hotter than the jet engines of the gunship. Aircraft launch these flares to throw the missiles off their tail, allowing planes to escape.

© Alamy

Silk spinners

Thes are the tiny structures that give spiders their silk-spinning ability. Known as spinnerets, six telescopic projections are found at the end of the spider's abdomen and are internally connected to silk-producing glands. At the tip of the spinnerets are nozzle-like structures called spigots, which release a chemical cocktail from the glands that forms robust silk when exposed to oxygen in the air.

© Getty

Anemonefish embryos

This sea of fish eyes is made up of hundreds of saddleback clownfish (*Amphiprion polymnus*) embryos stuck to rocks under a protective sea anemone. The fish eggs are adhered to the rocks by the female clownfish, while the male spends his time fanning them with water to keep them aerated. It only takes around eight days for the eggs to hatch.

© Getty

Fiery protostar

The James Webb Space Telescope has captured this explosive image of the protostar L1527. The glowing orange and blue clouds are created from cosmic dust and gas blasting away from the central protostar. The clouds appear orange at their thickest in this infrared image and blue at their thinnest. The central star is relatively young, cosmically speaking, at only 100,000 years old.

© NASA, ESA, CSA, and STScI, J. DePasquale (STScI)

An illustration of a 'runaway' black hole zooming away from its galaxy with a trail of stars following behind it

SPACE

'Runaway' black hole caught speeding through space

WORDS ROBERT LEA

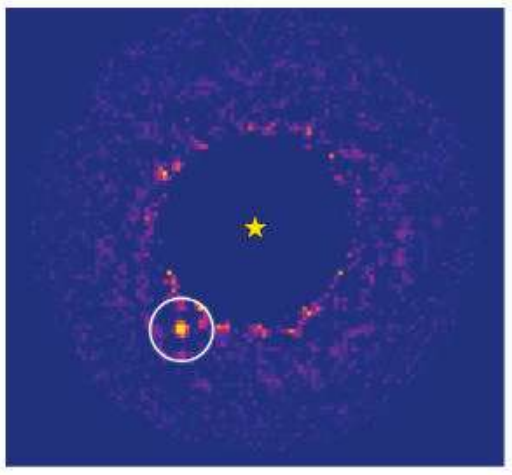
Astronomers have spotted a runaway supermassive black hole, seemingly ejected from its home galaxy, racing through space with a chain of stars trailing in its wake. The discovery offers the first observational evidence that supermassive black holes can be ejected from their home galaxies to roam interstellar space. Researchers discovered the runaway black hole as a bright streak of light while they were using the Hubble Space Telescope to observe the dwarf galaxy RCP 28, which is located about 7.5 billion light years from Earth.

Follow-up observations showed that the streak measures more than 200,000 light years long, roughly twice the width of the Milky Way, and is thought to be made of compressed gas that is actively forming stars. The gas trails a black hole that is estimated to measure 20 million times the mass of the Sun and is speeding away from its home galaxy at 3.5 million miles per hour. The streak points right to the centre of a galaxy, where a supermassive black hole would normally sit. "We found a thin line in a Hubble image that's pointing to the centre of a galaxy," said Pieter van Dokkum, a professor of physics and astronomy at Yale University. "Using the Keck telescope in Hawaii, we found that the line and the galaxy are connected. From a detailed analysis of the feature, we inferred that we are seeing a very massive black hole that was ejected from the galaxy, leaving a trail of gas and newly formed stars in its wake."

Most – if not all – large galaxies host supermassive black holes at their centres. Active supermassive black holes often launch jets of material at high speeds, which can be seen as streaks of light that superficially resemble the one the researchers spotted. These are called astrophysical jets. To determine that this isn't what they observed, van Dokkum and the team investigated this streak and found it didn't possess any of the telltale signs of an astrophysical jet.

While astrophysical jets grow weaker as they move away from their source of emission, the potential supermassive black hole tail actually gets stronger as it progresses away from what seems to be its galactic point of origin. Also, astrophysical jets launched by black holes fan out from their source, whereas this trail seems to have remained linear.

The team concluded that the explanation that best fits the streak is a supermassive black hole blasting through the gas that surrounds its galaxy while compressing that gas enough to trigger star formation in its wake. "If confirmed, it would be the first time that we have clear evidence that supermassive black holes can escape from galaxies," van Dokkum said. Once the runaway supermassive black hole is confirmed, the next question that astronomers need to answer is how such a monstrous object gets ejected from its host galaxy. "The most likely scenario that explains everything we've seen is a slingshot caused by a three-body interaction," van Dokkum said. This might mean that the runaway black hole was once part of a rare supermassive black hole binary, and during a galactic merger, a third supermassive black hole was introduced to this partnership, flinging out one of its occupants.



The newfound exoplanet HIP 99770 b is seen circling its host star in these images by the Subaru Telescope

SPACE

NEW STAR-MAPPING TECHNIQUE FINDS A GIANT EXOPLANET

WORDS **ANDREW JONES**

Astronomers have directly detected and imaged a gas giant orbiting another star by combining different techniques for hunting exoplanets. Researchers first looked at a catalogue of star-mapping data combined from the European Space Agency's Gaia and older Hipparcos missions to identify stars that, based on their apparent movements or wobbles, are likely to be orbited by giant – and thus potentially visible – planets. The international team of scientists then used the National Astronomical Observatory of Japan's Subaru Telescope on Mauna Kea, Hawaii. Observations using the telescope's coronagraphic adaptive optics and spectrograph instruments in July and September 2020 and May and October 2021 led to the discovery of the exoplanet HIP 99770 b.

HIP 99770 b is a gas giant planet about 15 times the mass of Jupiter orbiting the star HIP 99770, which is around twice as massive as our Sun. Direct imaging provides information such as the composition of atmospheres around planets and their temperatures. But actually finding planets in this fashion is very difficult, accounting for only a handful of exoplanet discoveries.

CHEMISTRY

Scientists discover the first 'neutron-rich' isotope of uranium since 1979

WORDS **ROBERT LEA**

Scientists have discovered and synthesised an entirely new isotope of the highly radioactive element uranium, but it might last only 40 minutes before decaying into other elements. The new isotope, uranium-241, has 92 protons and 149 neutrons. While the atoms of a given element always have the same number of protons, different isotopes, or versions, of those elements may hold different numbers of neutrons in their nuclei. To be considered neutron-rich, an isotope must contain more neutrons than is common to that element.

Uranium is in the class of elements in the periodic table known as 'actinides', which have proton counts between 89 and 103. All actinides are radioactive, but uranium is one of the four most radioactive elements, alongside radium, polonium and thorium. "We measured the masses of 19 different actinide isotopes with a high precision of one part per million level, including the discovery and identification of the new uranium isotope," said Toshitaka Niwase, a researcher at the High Energy Accelerator Research Organization's (KEK) Wako Nuclear Science Center (WNSC) in Japan. "This is the first new discovery of a uranium isotope on the neutron-rich side in over 40 years."

Isotopes can be stable, meaning they keep their atomic configuration, or unstable, meaning they decay and break down into other elements by gaining or shedding protons. Decay rates are measured by an isotope's half-life, or the time it takes for half the material to decay into other elements. After two half-lives, a quarter of the material remains. After three, an eighth, and so on.

The team hasn't yet measured the half-life of uranium-241, but theoretical estimates put it at around 40 minutes. This is somewhat short for a half-life. For example, the half-life of carbon-14 is 5,730 years, the half-life of the very unstable isotope technetium-99m is six hours and the half-life of francium-223 is 22 minutes. The fastest decaying isotope, hydrogen-7, is half gone in just 10^{-23} seconds.

Niwase and colleagues created uranium-241 by firing a sample of uranium-238 at platinum-198 nuclei. The two isotopes then swapped neutrons and protons in a phenomenon called 'multinucleon transfer.' The team then measured the mass of the created isotopes by observing the time it took the resulting nuclei to travel a certain distance through a medium. The experiment also generated 18 new isotopes, all of which contained between 143 and 150 neutrons.

Uranium-241 probably doesn't have many useful practical or scientific implementations, as the isotope is created in extremely small numbers.

Did you know?

An atom of uranium has 92 protons and 92 electrons

An example of uranium nitrate, called uranyl, with some uranium ore

© Getty / NASA, ESA, Leah Hustak (STScI) / T. Currie (Subaru/UTSA)

An artist's illustration of two brilliant-blue quasars about to collide in the early universe

SPACE

An ultra-rare 'double quasar' is spotted by Hubble

WORDS JOANNA THOMPSON

After 33 years, the Hubble Space Telescope is still uncovering new cosmic surprises. The venerable instrument recently added to its extensive catalogue of finds when it spotted a rare double quasar blazing away in the distant reaches of the universe. Quasars are among the brightest objects in the universe, emitting more light than the entire Milky Way. They form when gas, dust and other bits of matter fall into a supermassive black hole at the centre of a galaxy. Some of these particles become extremely luminous as they accelerate to near-light speed, all thanks to friction and the massive gravity exerted on them by the black hole.

In addition to being bright, quasars tend to be very old; it takes a long time to gobble up enough matter to become so gargantuan. The newly discovered quasar pair is no exception. They appear to have formed around 10 billion years ago. Scientists theorise that such objects were hallmarks of the early universe. But the twin nature of these objects makes them particularly exciting. "We don't see a lot of double quasars at this early time in the universe," said Yu-Ching Chen, a researcher at the University of Illinois at Urbana-Champaign.

Because of the way light bends around a massive gravity source – an effect called gravitational lensing – it can be difficult for scientists to determine whether an apparent double quasar is genuine or an optical illusion. But in this case astronomers were able to use ground-based telescopes to double-check Hubble's work. They used data from the W. M. Keck Observatory in Hawaii to confirm that the quasars were a binary system, rather than a trick of the light.

Despite the recent discovery, the double quasar likely no longer exists. In the intervening aeons from the light leaving the quasars to the moment it was picked up by Hubble, they have likely collided and merged with one another into a single black hole even more massive than the two that went into it. Likewise, the galaxies orbiting them have probably become one gigantic elliptical galaxy. Scientists believe that studying mergers like these could help us piece together a deeper understanding of how galaxies like our own came to be.

Hubble is scheduled for decommissioning in 2026, but that doesn't mean astronomers will have to give up quasar hunting. One of its successors, NASA's Nancy Grace Roman Space Telescope, is set to launch in 2027. This instrument will peer into a similar slice of the electromagnetic spectrum as Hubble, but with an even wider view, making it ideal for tracking down quasars.

ANIMALS

WOOLLY MAMMOTHS WEREN'T ALWAYS SHAGGY

WORDS JENNIFER NALEWICKI

Woolly mammoths weren't always the shaggy beasts depicted in movies. Scientists now have a better idea of when these behemoths evolved some of their iconic traits. Researchers from Sweden compared the genomes of 23 Siberian woolly mammoths (*Mammuthus primigenius*) to the genomes of 28 modern-day Asian elephants (*Elephas maximus*) and African elephants (*Loxodonta*). They found that over the course of the fauna's more than 700,000 years of existence, its 'trademark features', such as woolly fur, small ears and large fat deposits, evolved too.

"We wanted to know what makes a mammoth a woolly mammoth," said David Díez del Molino of the Centre for Palaeogenetics in Stockholm. "Woolly mammoths have very characteristic morphological features, like their thick fur and small ears, that you obviously expect based on what frozen specimens look like, but there are also many other adaptations, like fat metabolism and cold perception, that are not so evident because they're at the molecular level." The species' defining traits, such as fluffy fur, fat deposits and ability to weather cold conditions, were present when the woolly mammoth diverged from the steppe mammoth (*Mammuthus trogontherii*), one of its ancestors.

Woolly mammoths evolved to have fuzzy coats and small ears

HEALTH

Nearly 150 cartilage genes may control human height

WORDS **SASCHA PARE**

Cells that make up the cartilage at the ends of children and teens' bones determine their future length and shape, which affect height

Scientists have pinpointed 145 potential 'height genes' in cells that make up the cartilage at the ends of children's bones and affect how tall they grow. These cartilage cells, known as chondrocytes, multiply and mature in areas of tissue called growth plates, which sit near the ends of long bones in children and teens and determine each bone's future length and shape. When a person's growth is complete, these cartilaginous growth plates 'close' and are replaced by hard bone.

Scientists already knew that chondrocytes play a role in bone growth and human height, but narrowing down which genes control the cells' growth, and thus our stature, has proved difficult. "Pinpointing specific genes associated with human height is a challenging task, as height is a complex trait that's influenced by both genetic and environmental factors," said Dr Nora Renthal, a paediatric endocrinologist at Harvard Medical School. "Our study focused on cartilage cells specifically because they are the primary cell type involved in bone growth."

In the recent study, Renthal and her colleagues screened 600 million mouse cartilage cells to find genes that influence how the cells proliferate and mature. They used CRISPR genome-editing technology to 'knock out' candidate genes, which allowed the researchers to observe what happened when these genes were erased and no longer regulated cartilage cells. The researchers found 145 genes that, when knocked out, triggered abnormal growth and development of mouse cartilage cells. These patterns of abnormal growth were similar to those seen in certain skeletal disorders, such as skeletal dysplasia, a group of genetic disorders that affect the development of bones, joints and cartilage in babies. Those with skeletal dysplasia are typically of short stature and have short limbs, among other symptoms.

Did you know?

A baby has about 300 bones at birth, but an adult has 206

The researchers compared these 145 mouse genes with previous results from large-scale genetic studies of human height, called genome-wide association studies (GWAS). In those studies, researchers compared the DNA of thousands of people of different heights to look for gene variants associated with height. To control for non-genetic factors that influence the trait under study, such as nutrition and disease, these factors are incorporated into GWAS.

"These studies have contributed to our understanding of the genetic basis of complex traits like height by identifying specific genetic regions and genes that are associated with the trait," Renthal said. The comparison revealed a remarkable overlap between genetic 'hotpots' linked to human height in the GWAS and the 145 genes that control cartilage cell growth in mice. This means that these genes, which the researchers have now precisely located in the human genome, could influence height more than other genetic factors do.

"Our current study has helped identify new genes potentially involved in bone growth and development," Renthal said. "Specific genes and pathways involved in the maturation and proliferation of chondrocytes – the cells that make up cartilage in our bones – play a critical role in human height." Results from mouse cells may not mirror cellular processes in humans, but the researchers think height genes could come in handy in clinical settings. "It's our hope that the identification of these 145 genes will help patients with skeletal dysplasia and other skeletal disorders."

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ARCHAEOLOGY

A 30,000-year-old fur ball is actually a mummified squirrel

WORDS **HARRY BAKER**

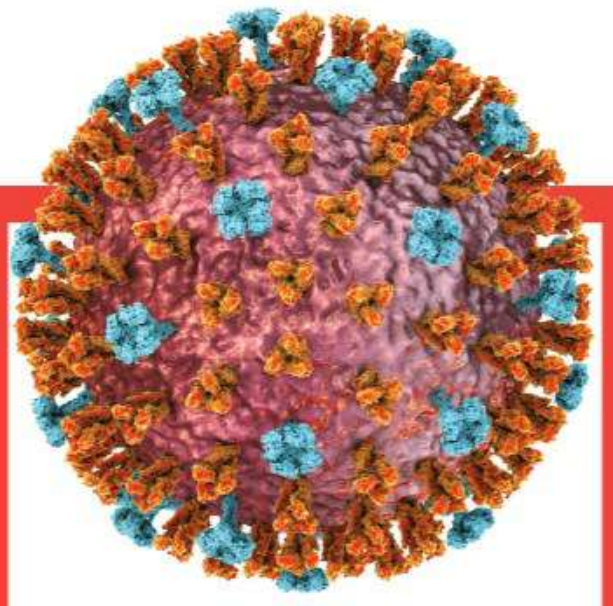
An unrecognisable ball of fur, claws and limbs that was recently unearthed in Canada is actually a mummified squirrel that likely died while it hibernated around 30,000 years ago. The strange fur ball was discovered in 2018 by miners at Hester Creek in the Klondike gold fields in Canada's Yukon territory. But scientists recently reevaluated it in preparation for its upcoming public debut at the Yukon Beringia Interpretive Center (YBIC) in Whitehorse. The lump is believed to be a curled-up Arctic ground squirrel (*Urocitellus parryii*). This species, which looks more like modern-day gophers than most squirrels, still exists today and lives in the region where the mummified ball was unearthed. Researchers have nicknamed the squirrel Hester after the area where it was found.

"It's amazing to think that this little guy was running around the Yukon several thousand years ago," said YBIC representatives. When researchers first found the balled-up squirrel, it was not immediately obvious what it was. "It's not quite recognisable until you see these little hands and these claws, and you see a little tail, and then you see ears," Grant Zazula, a palaeontologist with the Yukon government, said.

When the researchers realised they had found a 'perfectly preserved' squirrel, they were very excited. The researchers believe that Hester was most likely hibernating when he died. Living Arctic ground squirrels curl up into balls like Hester to hibernate inside underground dens, which they often line with leafy nests. Researchers have found examples of these preserved nests, but they are almost always empty.

The researchers didn't want to unravel the squirrel from its ball for fear that it may get damaged in the process, so it was X-rayed by local veterinarian Dr Jess Heath to get a better sense of how well preserved its insides were. Heath had predicted that the squirrel's bones would likely have deteriorated as calcium leaked out over time, which would likely mean the interior of the ball was in poor condition. However, the X-ray scans revealed that the squirrel's skeleton was in great condition, and the creature appeared almost identical to a living Arctic ground squirrel.

This lump of fur and claws is actually a balled-up mummified squirrel



Avian Influenza A (H3N8) is a subtype of bird flu that has only infected three humans to date

HEALTH

CHINA REPORTS THE FIRST HUMAN DEATH FROM H3N8 BIRD FLU

WORDS **NICOLETTA LANESE**

A woman in China recently died of H3N8, a subtype of bird flu that has only infected three known people to date. All three human cases of H3N8 have been reported in China. The first was reported in April 2022 and occurred in a four-year-old boy in Henan province, who likely caught the virus from chickens or wild ducks at his home. The second case occurred the next month in a five-year-old boy in Hunan province, who'd recently gone to a market where live poultry were sold, although he didn't directly handle the animals. The first boy's illness became severe and he required intensive care, but the second boy's case was mild. Both children recovered.

The newly reported third case was detected in a 56-year-old woman from Guangdong province, whose symptoms first emerged on 22 February 2023. She was hospitalised for severe pneumonia on 3 March and died on 16 March. The patient had multiple underlying conditions and had been exposed to live poultry prior to falling ill, as well as wild birds near her home. Researchers later collected samples from the patient's home and a nearby market, finding that samples from the market tested positive for influenza A (H3), the broad category of flu viruses to which the H3N8 subtype belongs. No evidence of human-to-human spread of H3N8 has been detected to date.

ANIMALS

The second-oldest orca in captivity is finally getting released

WORDS **HARRY BAKER**

Miami Seaquarium's star orca, Lolita, who has spent more than 50 years in captivity, will soon bid adieu to her tiny tank in Florida and live out the rest of her days in her home waters of the Pacific Northwest. Lolita, also known as Tokitae, is a 57-year-old orca (*Orcinus orca*) from the now-endangered Southern Resident orcas that live off the coasts of British Columbia, Washington and Oregon. She's the second-oldest orca in captivity behind Corky, a 58-year-old female who resides at SeaWorld San Diego. Lolita arrived at Miami Seaquarium in 1970 after a group of men captured her and 79 other orcas at a cove on Whidbey Island in one of the largest and most widely condemned orca-capture events in history. Since then, Lolita has lived and performed tricks in an aquarium pool, which is the smallest of its kind in North America, until March 2022, when she retired from public shows.

The decision to relocate Lolita to her home waters was announced 30 March at a press conference jointly held by the Dolphin Company, which owns Miami Seaquarium, and the conservation group Friends of Lolita, who have been campaigning for Lolita to be returned home since she retired. Lolita is too old to be successfully released into the wild, so she will be moved to a new sea pen where she will spend her retirement being looked after by trainers. It's unclear when Lolita will be moved and how large and where her new home will be.

In the wild, the average life span of female orcas is 46 years, but some can live for up to 80 or 90 years, while the average life span of males is only 30, although some can live for between 50 and 60 years. However, captive orcas rarely live this long. It's hoped that moving Lolita could potentially extend her life past what is possible in captivity. It's rare for captive orcas to be returned to the wild. The only captive orca from North America to be released into the wild was Keiko, who famously starred in the 1993 film *Free Willy*. Keiko was released in 2002 after a massive petition for his release, but he died from pneumonia in the waters of Norway in 2003, which sparked fears that orcas could not be reintegrated into the wild. However, in the BBC documentary *Frozen Planet II*, a formerly captive orca from Russia was filmed hunting and playing with a pod of orcas, which suggested that full integration into the wild is possible.

Did you know?

The largest orca ever recorded was a 9.8-metre-long male

Keeping orcas in captivity is highly controversial. Since 1961, when the first wild orca was captured, 174 orcas have died in captivity, and this figure doesn't include the 30 miscarried or stillborn calves from expecting captive mothers. Those that are able to survive in captivity have a poor quality of life and can suffer from a wide variety of health problems, such as dorsal fin collapse – particularly among males – and tooth damage.

Lolita performing alongside a trainer at the Miami Seaquarium in 2014

© Getty / Alamy / Government of Yukon

PLANET EARTH

The smallest and largest animals make up most of Earth's biomass

WORDS **ELANA SPIVACK**

Scientists have spent five years classifying the size, mass and population of all living organisms, and at the end they made a surprising discovery: the tiniest and largest living entities on Earth dominate by sheer mass. To tackle this gargantuan task, the team, led by biologists from Rutgers University in New Jersey and the University of British Columbia, divided life into 36 categories across terrestrial, marine and subterranean environments. Within each group they identified the biggest, smallest and most common body size. Then, combining that information with pre-existing data on each group's biomass, they estimated how much of Earth's biomass each category comprised. Forest plants had the highest biomass and amphibians had the lowest. Malin Pinsky, an associate professor in the department of ecology, evolution and natural resources at Rutgers University, said this sort of survey is "the first time this has ever been done".

In the 1960s, aquatic ecologists found total biomass concentration remained constant across wildly different scales, indicating that size was evenly distributed among various species. Pinsky said his team had expected to find "roughly the same amount of life at every body size," as previous studies also predicted. Instead the results revealed that nature favours size at its extremes. "The world we see often seems like it's full of lots of small insects and butterflies," Pinsky said. "And yet what we've discovered is actually those are sort of intermediate body sizes that aren't necessarily all that common." Rather, marine and soil bacteria, which are considered small, have more biomass than intermediately sized insects. The investigation also yielded that this pattern held across different types of species, and was even more evident in terrestrial creatures than marine dwellers.

As for humans, *Homo sapiens*' size may be large relative to that of another species, but human biomass can't compete with other biological groups. Setting this survey apart from other similar projects is its incorporation of groups like undersea microbes and producers like kelp and sea grasses, which previous studies excluded – they account for nearly half of ocean biomass.

Among the 36 categories, which included life forms such as reptiles and molluscs, the most massive populations belonged to plants and bacteria. Of these, the smallest were microscopic bacteria, while the largest included vast underground networks of fungi and tree roots. These groups collectively dwarf the biomass of animals such as humans, livestock and wild terrestrial animals. And while humans are relatively large and fit into the bigger end of the size spectrum, our biomass can't compete with that of soil and marine protists that are invisible to the eye. "Besides whales, there are no other organisms bigger than corals and mangroves," said Eden Tekwa, a quantitative ecologist and research associate at McGill University in Canada.

The study not only reveals how Earth's biomass is currently distributed, but also what the future may look like. Tekwa said the team quantified the amount of carbon in each group, finding smaller life forms generally have shorter life spans, so their carbon is released into the atmosphere at a faster clip, potentially contributing to climate change. "Body size is one of the most basic characteristics of life on Earth," Pinsky said. "Understanding how life is distributed across different body sizes is fundamental to understanding life on Earth."

Giant and tiny creatures comprise the bulk of Earth's biomass

Did you know?

Around 1.2 million species have been identified so far

The fungus behind a plant disease called ‘silver leaf’ recently infected a human

HEALTH

Man catches ‘silver leaf’ tree fungus disease

WORDS **NICOLETTA LANESE**

In a first-of-its-kind medical case, a man in India contracted a fungal disease that typically affects trees and had never been reported in a human before. The 61-year-old man had difficulty swallowing, hoarseness, cough, lack of appetite, fatigue and recurrent inflammation of the throat for about three months before seeking medical care. The patient works as a mycologist, meaning he studies fungi, and he reported regularly working with decaying material, mushrooms and other fungi as part of his research.

A computerised tomography (CT) scan of the man’s neck revealed a pocket of pus on the right side of his windpipe. The patient’s doctors extracted a sample of pus from this abscess, analysed it and found evidence of fungal growth. By applying a stain to the sample, the team revealed a number of branching filaments called hyphae, which are found in fungi. And in another test, the team allowed the pus to incubate in a lab dish and found that it grew a ‘creamy, pasty colony’ of fungus within a few days. The fungal species could not be identified from its physical features, so the team sent a sample off to the World Health Organization (WHO) Collaborating Centre on Reference and Research on Fungi of Medical Importance in India. Through genetic analysis, the WHO researchers identified the fungus as *Chondrostereum purpureum*, which causes a disease called silver leaf in plants.

“The patient denied having worked with such a plant pathogen, but he confirmed that he was working with decaying material and other plant fungi for a long time as part of his research activities,” the case doctors wrote in their report. The patient’s infection was successfully treated with a procedure to drain the pus from his neck, followed by a two-month regimen of broad-spectrum antifungal pills. After two years of follow-up monitoring, “the patient was absolutely fine, and there is no evidence of recurrence,” his doctors reported.

C. purpureum infects a wide range of trees, including fruit-bearing trees like apple, pear and cherry trees, as well as ornamental trees like maples, oaks and elms. Infected trees develop a silver sheen on their leaves, as the infection causes the outermost layer of the leaves to separate from the layers beneath. Since this is the first time a *C. purpureum* infection has been observed in a human, it’s unclear how likely it is to occur in others or how such infections can best be treated.

SPACE

EUROPE PREPARES THE DARK MATTER-HUNTING EUCLID SPACECRAFT FOR LAUNCH

WORDS **ANDREW JONES**

Europe’s newest space telescope is set to cross the ocean ahead of its voyage to space this summer. The Euclid spacecraft recently completed a rigorous environmental and mechanical testing program at a facility in Cannes, France. Euclid has been transported by road to the port of Savona in Italy and will soon set sail for a port near its launch site, Florida’s Cape Canaveral Space Force Station. The telescope is due to launch on a SpaceX Falcon 9 rocket in July.

The spacecraft, named for the Greek mathematician Euclid of Alexandria, will map the geometry of matter in the universe and investigate the history of its accelerating expansion. By looking at galaxies up to 10 billion light years away, Euclid aims to provide insight into how dark energy and dark matter have impacted the development of the cosmos and the mysteries of the dark universe itself. After launch, Euclid will have a roughly 30-day journey to the Sun-Earth Lagrange point L2. L2 is a gravitationally stable area around one million miles away; it’s inhabited by other observatories, including the James Webb Space Telescope.

Technicians at a Thales Alenia Space facility in France prepare the Euclid space telescope for its sea voyage to Florida

© Getty / Thales Alenia Space

WISH LIST

The latest MUSIC GADGET tech

BEATBOX

WWW.RHYTHMO.IO $159.99 (APPROX. £128.10)

The BeatBox is a DIY drum machine kit that's perfect for beginners looking to advance their music knowledge and get to grips with basic musical tools. Everything you need to build the BeatBox comes with the kit, which takes around an hour to assemble– no soldering required. Once you're up and running, the DIY device connects to a tablet or smartphone with the Rhythmo Lab companion app. Within the app there are heaps of guided tutorials to teach you about music production and how to get the best out of the 16 performance buttons. The BeatBox is also portable and is powered by a battery pack that tucks away into the cardboard casing.

MW08 EARPHONES

WWW.MASTERDYNAMIC.CO.UK £319/ $299

The sleek and stylish MW08 earphones by Master & Dynamic are crafted from lightweight and scratch-resistant ceramic and stainless steel, available in nine different colours. There are two modes of active noise cancellation within the MW08 and two modes of ambient listening transparency to block out the world around you. There are also six built-in wind-resistant microphones to keep your phone calls crystal clear. The MW08 boasts 12 hours of playtime, and the accompanying stainless-steel charging case can deliver an additional 30 hours of charge. In just 60 minutes the charging case can completely refuel the earphones, but if you're in a rush then it can charge them back to 50 per cent in just 15 minutes using fast charging.

LUMI KEYS

WWW.PLAYLUMI.COM FROM £299 / $299

If you're looking to learn how to play the piano at home or you're a producer looking to record your ideas on the fly, it might be worth checking out LUMI Keys. As a teaching tool, what's great about LUMI is the feedback users get from its companion app. As music plays on the screen, the corresponding keys are illuminated in real time so you can play along. For advanced players, the LUMI offers an efficient and compact way to compose music through the LUMI Keys Studio software. This mini portable controller can easily fit in a backpack or handheld luggage for music on the go. If you're looking to build a keyboard, the LUMI is also modular, so you can connect multiple devices to make a larger instrument.

ORBA

WWW.ARTIPHON.COM £89.99 / $99.99

Meet the Orba, a handheld synthesiser that lets you make music wherever you are. Using the Orba's integrated looper and recording features, you can layer drums, bass and chords to make music in minutes. Around the same size as a halved orange, this compact musical instrument can fit comfortably in the palm of your hand. What's really impressive about the Orba is how it's played. There are ten core gestures players can use to create sound, including a simple tap, tilting the device and shaking it. Each of the touch-sensitive pads has motion sensors that can capture micro-movements to give you the best control of the sound. The Orba also comes with a speaker and jack connection, allowing you to create in both public and private.

DD70 PORTABLE ELECTRONIC DRUM PAD PACK

WWW.GEAR4MUSIC.COM
£159.99 / $178.75

Packing the same punch as a full drum kit, the DD70 is a compact and portable set that lets you create a catchy rhythm wherever you are. It comes with seven touch-sensitive drum pads and two pedals. The electric drum kit comes with 265 different percussion sounds and 100 different backing tracks. The DD70 is a fraction of the weight of a traditional drum kit and comes with an X-frame keyboard stand to raise the drum pads. This allows musicians to set up in small spaces or while on the move and whenever inspiration strikes. You also won't have to worry about disturbing the neighbours during a jam session thanks to the jack connection, allowing you to plug in a pair of headphones.

JOUÉ PLAY

WWW.JOUEMUSIC.COM £255 / $294.99

The Joué Play is a modular controller that uses silicone interfaces to simulate a variety of instruments. Its intuitive design means that to change instruments you need only swap the silicone interface and the Joué Play automatically detects the change. Ready to go right out of the box, its plug-and-play nature means you can have access to a whole host of instruments in minutes. There's also the option of exploring the user-friendly companion app that removes the need for overly complex music software, allowing beginners and advanced music producers alike to sharpen their musical skills.

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WORLD'S OLDEST LIVING PLANTS
HOW IT WORKS
Cats vs dogs
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SPACE TRAVEL OF THE FUTURE
SEE INSIDE A PINBALL MACHINE
IS 'MUSCLE MEMORY' A REAL THING?
HOW WHALES AND DOLPHINS SLEEP
ANATOMY OF A CAR CRASH
CATS CAN HEAR HIGHER FREQUENCIES THAN DOGS
THEIR EYES EVOLVED FOR BETTER HUNTING
THEY HAVE A BETTER SENSE OF SMELL
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SPECIAL

Cats vs dogs

How the psychology and biology of the world's most popular pets compare

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? 15 minutes of petting a dog can lower blood pressure by ten per cent

Humankind's canine companions and feline friends belong to an order of animals called Carnivora. They are both the descendants of the first mammals of the late Paleocene epoch that hungered for the flesh of other animals. Between 65 and 35 million years ago, an order of weasel-like animals called *Miacis* skulked through the trees of ancient woodlands across Eurasia and North America. These furry mammals were arboreal creatures, meaning they spent their time hunting among the lush vegetation of the Paleocene forest. Although *Miacis* was one of the earliest carnivorous mammals on Earth, it was by no means the most ferocious.

Following the extinction of the dinosaurs around 66 million years ago, two mammalian hunters rose to the top of the food chain: wolf-like predators called creodonts and the hoof-footed ancestors of marine mammals, called mesonychids. Both of these apex predators met their extinction due to an overlap of resources and competition with other carnivores. *Miacis*, on the other hand, began a lineage of mammals that resulted in the evolution of prolific predators in the modern world, such as lions, tigers and bears. Around 43 million years ago, the carnivorous descendant of *Miacis* diverged into two distinct paths – the 'dog-like' Caniformia and the 'cat-like' Feliformia. Over millions of years, these animals evolved into the array of feline and canine species seen today, including the domestic cat and dog.

Did you know?

Dogs have around 100 more bones than cats

The evolutionary road to becoming the cats and dogs we know today didn't occur through typical means. Unlike the pressures of natural selection that their wild cousins have endured for millennia, cats and dogs owe their current form to their interactions with humans. Dogs were the first to find human companionship around 23,000 years ago. Some of the most recent genetic research suggests that prehistoric grey wolves and humankind evolved in tandem in Siberia in the late Pleistocene. Over thousands of years of benefiting from hanging around one another for food and safety, prehistoric people likely bred the tamest of wolves into domesticated allies.

Cats, on the other hand, befriended people around 10,000 years ago. It's long been believed that ancient Egyptians were the first to tame wild cats and keep them as pets. Depicted in hieroglyphs as magical creatures and mummified along with their human owners, cats played a significant role in the lives of those that lived 3,600 years ago. However, this is far from the first time cats and

"Following the extinction of the dinosaurs around 66 million years ago, two mammalian hunters rose to the top of the food chain"

Rather than a quick sniff of the behind, cats touch noses to say hello to each other

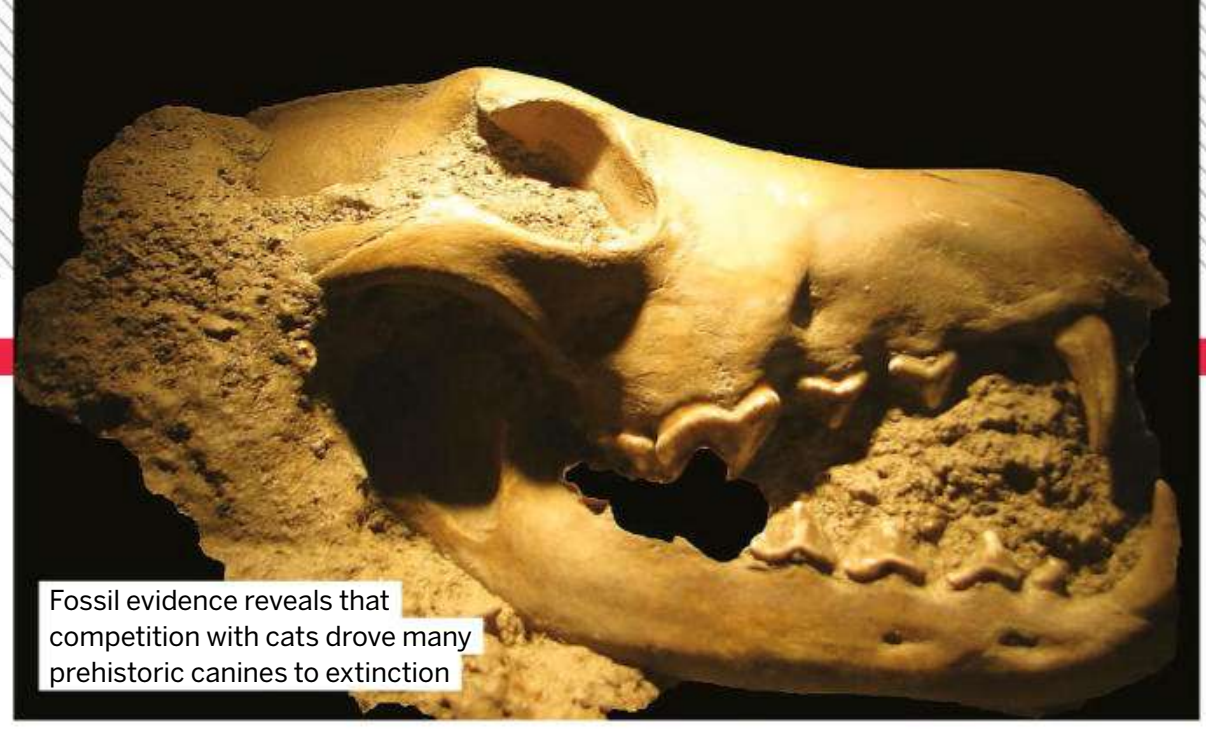
© Getty

humans cohabited. Researchers have examined the DNA of the common household cat's wildcat ancestor (*Felis silvestri*) and traced it back to the first human settlements in the Middle East, known as the Fertile Crescent and also referred to as the cradle of civilisation. It remains unclear exactly why cats found their way into our lives, but some DNA evidence suggests that they may have self-domesticated. As hunters of pesky rodents, ancient farmers likely kept cats around.

Did you know?

The average dog can learn 165 words

Most of the dog breeds we recognise today developed in the last 150 years. However, the oldest domesticated dog breed is the Saluki. Mummified remains of these slender pooches that have been found in Egypt have been dated to 329 BCE. There have also been carvings found in Iraq that resemble the Saluki, dating back to 7,000 BCE. At present, there are around 340 unique dog breeds and 42 breeds of cat. Scientists suggest that extended periods of selective breeding for both functional and aesthetic qualities, such as herding and hunting skills, as well as coat colour and size, have led to the creation of modern-day canines. Cats have been less selectively bred for their abilities and remain relatively similar in



Fossil evidence reveals that competition with cats drove many prehistoric canines to extinction

PREHISTORIC RIVALS

Cats and dogs have long been rivals. In 2015, researchers from the University of Gothenburg in Sweden, São Paulo in Brazil and Lausanne in Switzerland analysed more than 2,000 fossils and discovered that prehistoric cats contributed to the extinction of up to 40 different species of the canine family. Around 22 million years ago, when dog diversity was at its peak in North America, researchers discovered typical causes of extinction, such as climate change, that were as deadly to prehistoric dogs as competition from resourceful felines. The research concluded that prehistoric felids were likely more efficient predators and out-hunted many prehistoric dog species for food.

COMMON ANCESTOR

Miacids were the prehistoric ancestors of both cats and dogs

4 ADAPTED FEET
As arboreal creatures, their hind feet were capable of turning backwards to grip trees.

3 SMALL PREDATORS
Miacids had a diverse range of body sizes, from one to seven kilograms.

2 CARNIVORES
These prehistoric predators likely hunted and fed on reptiles, birds, insects and other small mammals.

5 PREHENSILE TAIL
Like many tree-dwelling animals, miacids had tails that could grasp onto branches.

1 CLAWS
Miacids had five-clawed paws to scale trees and grapple with prey.

DID YOU KNOW? In 1963, a stray Parisian cat named Félicette became the first feline to be sent into space

Family tree

Discover the closest living relatives of cats and dogs

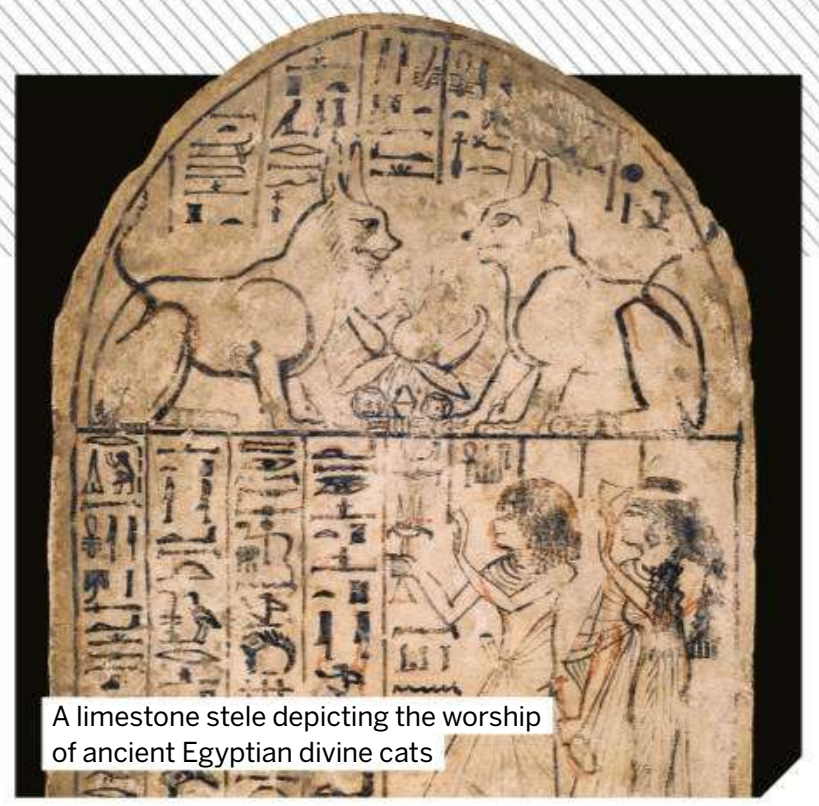
- **Carnivora**
  - **Feliformia**
    The suborder that encompasses the world's species of 'cat-like' animals.
    - **Nandiniidae** — Only one animal belongs to this feline family: the African palm civet.
    - **Stenoplesictidae**
    - **Percrocutidae**
    - **Feloidea**
      A superfamily that compasses smaller Feliformia families, including civets and the domestic cat.
      - **Prionodontidae**
      - **Barbourofelidae**
      - **Felidae** — The family of animals that includes the world's big cat species, bobcats and domestic cats.
    - **Viverridae**
      Small feline-like families that include species such as the African civet and binturong.
      - **Viverridae**
      - **Herpestoidea**
        - **Hyaenidae**
        - **Herpestidae**
        - **Eupleridae**
  - **Caniformia**
    The suborder that encompasses the world's species of 'dog-like' animals.
    - **Amphicyonidae**
    - **Canidae** — Along with dogs, this family of 34 canids includes coyotes, foxes and wolves.
    - **Arctoidea**
      - **Hemicyoninae**
      - **Ursidae** — This family consists of the world's eight species of bear, including the brown bear, polar bear and giant panda.
      - **Pinnipedia**
        This suborder of animals comprises the world's seal and walrus families, with a total of 34 different species.
        - **Enaliarctidae**
        - **Phocidae**
        - **Otariidae**
        - **Odobenidae**
      - **Musteloidea**
        A suborder of small mammal families of 88 different species including skunks, raccoons and otters.
        - **Ailuridae**
        - **Mephitidae**
        - **Procyonidae**
        - **Mustelidae**

"Most of the dog breeds we recognise today developed in the last 150 years"

© Alamy / Getty / Michele Silvestro / Science Photo Library

5 SIGNS YOUR DOG LOVES YOU

Both are expert nappers, but cats spend a little bit longer sleeping than dogs



A limestone stele depicting the worship of ancient Egyptian divine cats

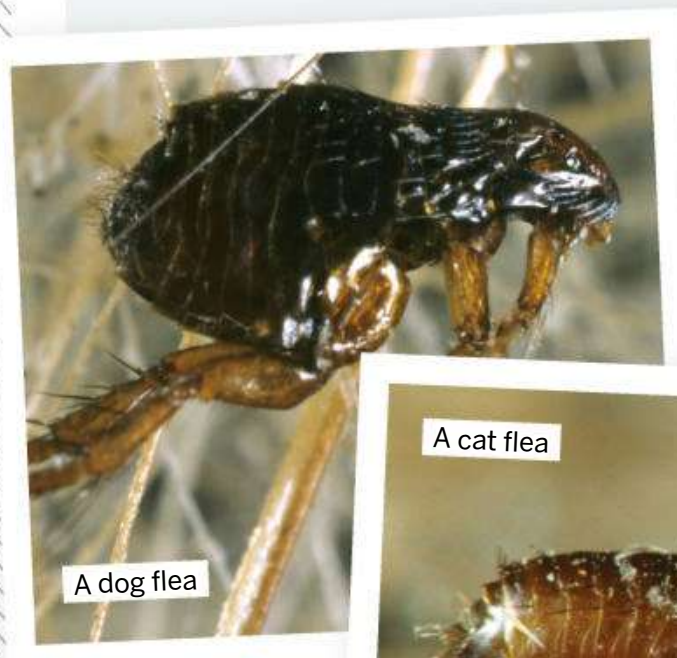
1 TAIL WAGGING
The movement of a dog's tail is a display of their current emotion. A wagging tail – sometimes in a circular motion – and a smiling face are a good sign your pup is pleased to see you.

2 LICKING
Similar to how their wolf ancestors licked their mothers for attention and food, if a dog likes you, a lick on the hand can mean they want your attention.

3 CUDDLING
When a dog chooses to jump up onto the sofa for a quick cuddle, it's a pretty good indication that they enjoy your company.

4 FOLLOWING
Over time, dogs come to associate their owner with things such as food and play, which release a happy hormone called oxytocin. They follow their owner around in case there's another hit of oxytocin on the way.

5 EYE CONTACT
Normally, dogs aren't that forthcoming with eye contact. However, when a dog chooses to look at you with soft, relaxed eyes, they're attempting to form a bond with you.



A dog flea

A cat flea

appearance to each other when compared to dog breeds. Despite the range of dog breeds, their DNA is only one per cent different from other breeds' on average, whereas individual cat DNA differs by up to four per cent.

Along with their obvious physical differences, the two don't have very much in common, except for both being great companions. One of the main differences between cats and dogs is their behaviour. As keen sleepers, both cats and dogs spend a considerable amount of time asleep. On average, felines spend up to 16 hours a day taking a cat nap, whereas dogs are a little more active, needing up to 14 hours of sleep. Cats are often thought of as nocturnal animals, when in fact they are crepuscular, which means that they are most active during dawn and dusk. It's thought this preference for low light relates to their behavioural adaptation to pounce on their prey during twilight. By contrast, dogs spend up to 80 per cent of their time asleep during the night, known as diurnal sleeping.

The pair also have different dietary requirements. Cats need a higher source of meat protein and vitamin A than that found in a dog's diet. This is mostly because cats are unable to produce important amino acids, such as taurine, and have to source it directly from their food. Dogs can produce these proteins in their body and therefore have a broader diet.

Did you know?

Cats can run at top speeds of 30 miles per hour

'Fighting like cats and dogs' is a phrase that's often bandied around to describe conflict, but the idea that these pets are mortal enemies isn't exactly true. When a dog sees smaller furry animals running quickly away from them, their built-in predatory instinct kicks into gear. In the same way it may respond to seeing a rat or rabbit, its instinctual response is to chase it. Cats typically respond in a defensive manner and are likely to take a swipe at an advancing dog. Similarly, the difference in their greeting styles can cause some tension. While dogs like to engage in a bit of butt sniffing to introduce themselves, cats greet each other by touching their noses together. This miscommunication can lead the pair to butt heads – and tails – from time to time. However, through periods of socialisation, especially effective when kittens and puppies coexist, the pair can form furry friendships that last a lifetime.

"Felines spend up to 16 hours a day taking a cat nap, whereas dogs are a little more active, needing up to 14 hours of sleep"

UNIQUE FLEAS

Along with their many physical and behavioural differences, cats and dogs also have their very own species of fleas: cat fleas (*Ctenocephalides felis*) and dog fleas (*Ctenocephalides canis*). At first glance you might be mistaken in thinking all parasites leaping through your pet's fur are the same. The anatomical differences between these fleas are small, with dog fleas having a more rounded head and more hair-like structures called setae. Cat fleas are much more common than dog fleas. Although they are named after their feline hosts, cat fleas can be found on a whole host of species, whereas dog fleas are limited to just their canine feeding grounds.

DID YOU KNOW? The oldest cat in the world, Creme Puff, lived for 38 years and three days

Dog diversity

On the surface, dog breeds are wildly different from their feline counterparts. For example, the largest dog breeds in the world are 40 times bigger than the smallest dog breeds. But when you dig deeper into the DNA of our canine and feline friends, there are some interesting differences. Despite all the colours, shapes and sizes of floppy ears, long tails and fluffy coats, there's only a tiny percentage difference in the DNA between the world's different dog breeds. Meanwhile, cats average a slightly larger average DNA difference among fewer cat breeds. Of the roughly 19,000 canine genes, variations in only 14 of them give rise to the many differences in appearance.

Along with a phenomenon called domestication syndrome, whereby the physical appearance of an animal changes in response to generational tameness, thousands of years of selective breeding have altered the combinations in dog DNA to create the hundreds of breeds we have today. Cats, on the other hand, have not experienced selective breeding on the same level as dogs, though there is still time. Over the next hundred years or so, floppy-eared felines, curly-haired cats and tall tabbies might become the norm.

The American Kennel Club found that the most popular dog breed in 2022 was the French Bulldog

The most popular cat breed in the US is the Ragdoll

MEET THE PET GENETICIST

Kennel Club genetics research manager Dr Joanna Ilska sheds some light on how dog breeds are defined

How is a new dog breed defined?
A breed is considered to be a population of dogs with clearly observable and heritable characteristics that have been attained by selective breeding over a period of time. The breed is documented through the pedigrees, tracking the ancestry of the individual dogs.

There are no specific genetic criteria which would determine whether a population can be described as a breed. From the point of view of genetics, a breed is simply a population of individuals, with all the genetic variants they possess. The genetic variants in a population evolve over time, as some variants will be lost through selection or random chance, while new variants will be added through novel mutations. As such, the breed population we see today is very likely to be genetically different to the same breed population many generations ago. Further, breed populations which are separated, geographically or through function, may also start to diverge genetically while still retaining the same observable breed characteristics.

Why are there so many more distinct dog breeds?
Dogs are highly social, with very well-developed instincts to cooperate with their pack members. This formed a fertile ground for selection for a whole range of different traits, where natural instincts inherited by dogs from their wild ancestors were shaped and moulded to specific functions benefiting humans in the process of domestication. Over time these functions became more and more specialised, leading to a range of behavioural and physical attributes unique to dogs performing these functions – from highly athletic and resistant to cold Siberian Huskies pulling sleds in the Arctic to short-legged Dachshunds hunting badgers in their burrows.

Domestication of cats has been far more limited – they still retain many of their 'wild' characteristics and are fully capable of surviving in the wild. Cats are less social than dogs or wolves and don't have the same propensity for cooperation. As such, early humans coexisted with cats benefiting from their natural desire to hunt vermin. While formal breeds – with breed standards and pedigrees in both dogs and cats – are a fairly recent phenomenon, dog breeds have been developed from already-existing populations specialising in specific roles. On the other hand, with few exceptions, cat breeds have been developed primarily for aesthetic value.

How long can it take for a new dog breed to emerge?
Historically, most breeds were created over long periods of time, with dogs gradually becoming more uniform as the best performing dogs were selected to produce subsequent generations. Nowadays, the knowledge of genetics allows for much faster progress, with a much more precise selection of the best individuals, as well as much easier access to breeding dogs from across the world. However, the exact time needed to create a new breed will vary depending on a number of factors.

Firstly, the speed with which uniformity can be achieved will depend on the number and type of traits that will differentiate this new breed. The fewer the traits and the simpler their genetic architecture – how many genes are involved and the mode of inheritance – the easier it will be to develop a uniform population. Secondly, the more diverse the dogs used as a founding stock for the new breed are, the more generations it will take before their descendants are uniform. Thirdly, there needs to be a balance between selection intensity and inbreeding. High selection intensity increases the speed with which uniformity can be achieved, but it also carries with it higher levels of inbreeding, which may reduce the health and fitness of the breed.

© Alamy / Getty / The Kennel Club

SPECIAL

Comparing companions

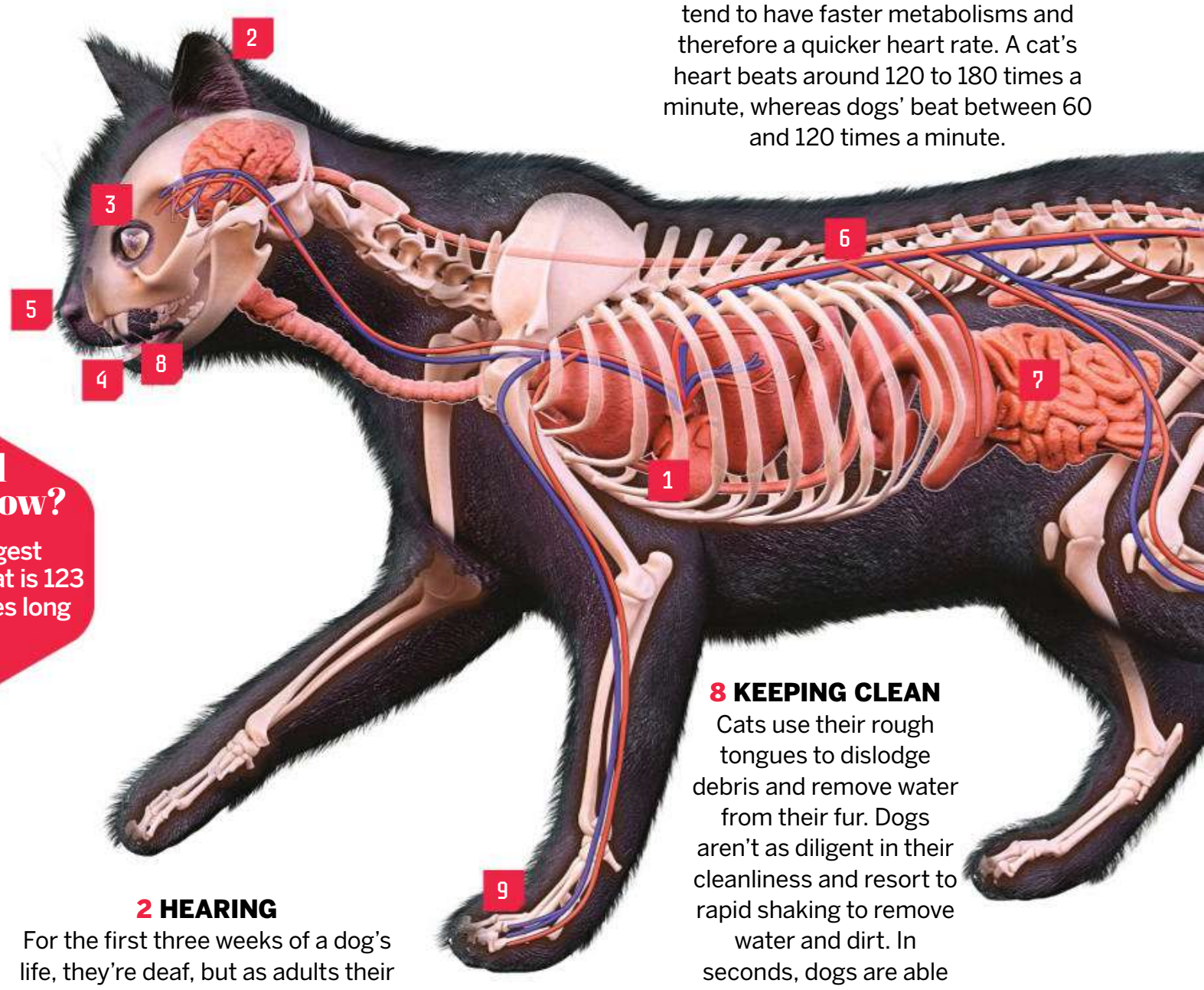
The physical similarities and differences between cats and dogs

As mammals, cats and dogs share a lot of similarities. They're both warm-blooded, air-breathing, fur-covered creatures, with almost all the same organs. However, there are some differences in their physiology. For example, their brains are set up slightly differently from one another. Typically, a dog has a bigger brain than a cat, and a larger portion of its mass is dedicated to the cerebral cortex. This part of the brain is responsible for receiving and processing sensory information – the smells, sights and sounds that a dog encounters – along with decision-making and social interaction.

Cats have developed a brain that favours areas such as the hippocampus that are responsible for memory development, navigation and movement. Dogs have twice the number of neuron cells that transmit information around the brain than cats. A group of researchers from institutions around the world analysed the brains of cats and dogs, along with lots of other carnivores, and found that the cerebral cortex of a dog had 530 million neurons, whereas cats had 250 million. It's not just domesticated cats that are beat out, but African lions and brown bears too. However, this doesn't necessarily mean that dogs are smarter than cats. Countless studies have been devoted to assessing the cognitive abilities of our furry companions, but no consensus has been made about their overall intelligence.

Did you know?

The longest domestic cat is 123 centimetres long



1 HEARTBEAT

Due to their sizes, cats and dogs have very differently sized hearts, but they're typically up to 1.25 per cent of their total body weight. However, smaller animals tend to have faster metabolisms and therefore a quicker heart rate. A cat's heart beats around 120 to 180 times a minute, whereas dogs' beat between 60 and 120 times a minute.

2 HEARING

For the first three weeks of a dog's life, they're deaf, but as adults their hearing is around four times stronger than humans'. Cats are capable of hearing much higher sound pitches than dogs – around a single octave.

5 SMELL

Dogs are proficient sniffers, with a sense of smell that's 100,000 times better than humans'. Dogs have up to 300 million smell sensors in their noses that can sniff out smells 12 metres underground. Cats aren't too shabby either, with 200 million odour sensors in their noses, giving them a sense of smell that's 14 times better than ours.

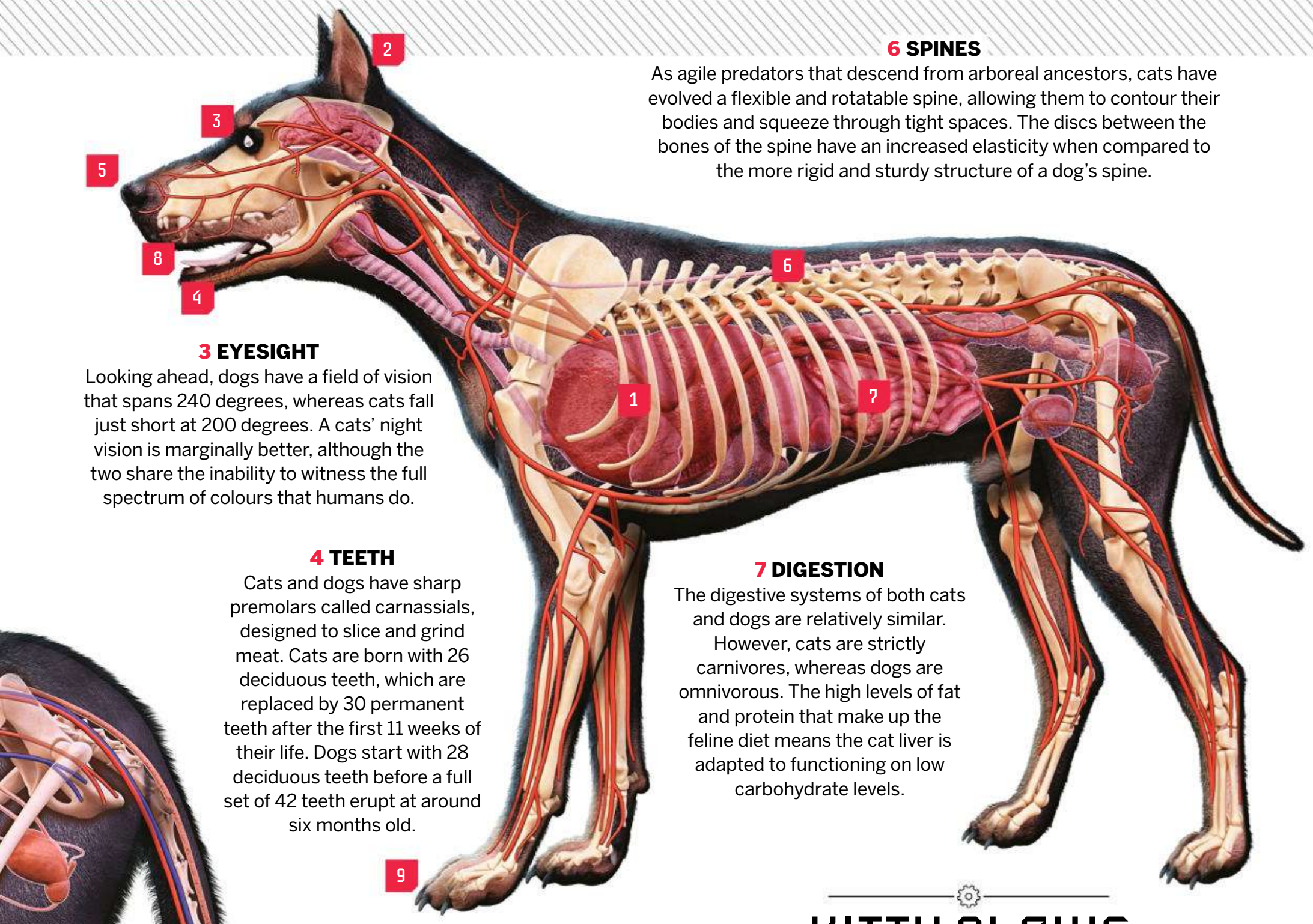
8 KEEPING CLEAN

Cats use their rough tongues to dislodge debris and remove water from their fur. Dogs aren't as diligent in their cleanliness and resort to rapid shaking to remove water and dirt. In seconds, dogs are able to shake off 70 per cent of the water in their fur.

9 CLAWS AND PAWS

A swipe from a cat and dog is a very different experience. Cats are armed with razor-sharp retractable claws that are designed for scaling trees, whereas dogs have evolved duller nails which grind down as they walk.

DID YOU KNOW? A harlequin Great Dane named Boo Boo holds the record for tallest dog, at 107 centimetres tall



6 SPINES

As agile predators that descend from arboreal ancestors, cats have evolved a flexible and rotatable spine, allowing them to contour their bodies and squeeze through tight spaces. The discs between the bones of the spine have an increased elasticity when compared to the more rigid and sturdy structure of a dog's spine.

3 EYESIGHT

Looking ahead, dogs have a field of vision that spans 240 degrees, whereas cats fall just short at 200 degrees. A cats' night vision is marginally better, although the two share the inability to witness the full spectrum of colours that humans do.

4 TEETH

Cats and dogs have sharp premolars called carnassials, designed to slice and grind meat. Cats are born with 26 deciduous teeth, which are replaced by 30 permanent teeth after the first 11 weeks of their life. Dogs start with 28 deciduous teeth before a full set of 42 teeth erupt at around six months old.

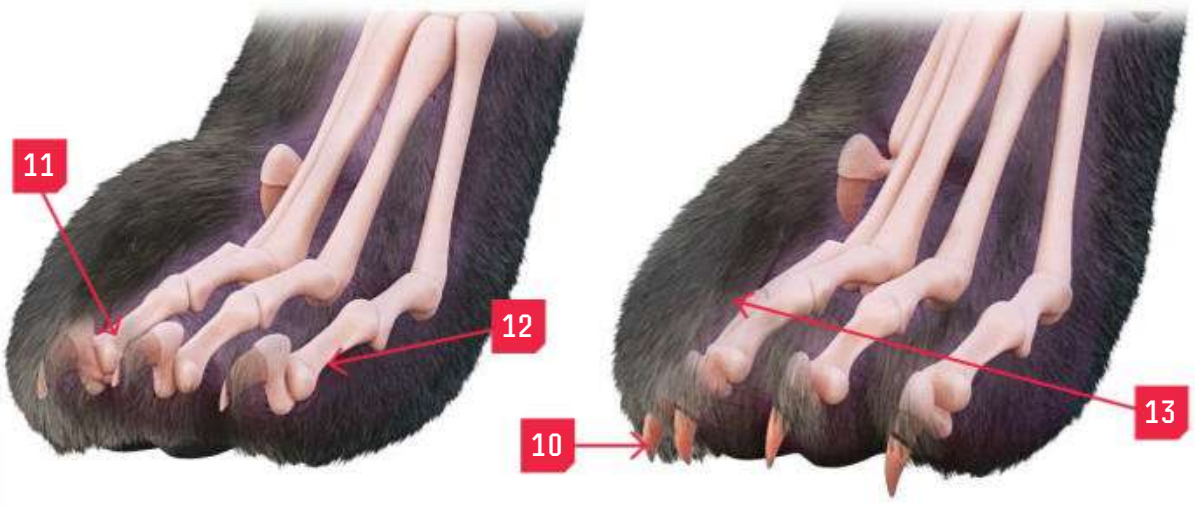
7 DIGESTION

The digestive systems of both cats and dogs are relatively similar. However, cats are strictly carnivores, whereas dogs are omnivorous. The high levels of fat and protein that make up the feline diet means the cat liver is adapted to functioning on low carbohydrate levels.

The Saluki is the oldest known modern-day dog breed, dating back to ancient Egypt

KITTY CLAWS

How cats retract their claws



10 CLAWS

Cats extend their claws and drag them down hard surfaces to keep them razor sharp.

11 ELASTIC LIGAMENT

This muscle contracts to retract the cat's claws when signalled to by the brain, tucking the claws back into the paw.

12 DIGITAL FLEXOR TENDON

When tightened, the tendon attached to the bone in the foot pulls the bone back and extends the claw outwards.

13 DIGITAL EXTENSOR TENDON

As the opposite of the flexor tendon, this muscle contracts to draw the cat's bone back, bringing the claw with it.

© Getty / Illustrations by Nicholas Forder

SPECIAL

Cats and dogs by numbers

95.6%
Domestic cats share the majority of their DNA with tigers

The collective noun for a group cats is a 'clowder'

THREE TIMES
A cat's whiskers, or vibrissae, have roots that are much deeper than regular hairs

90 decibels
A dog's bark can reach volumes as loud as power tools

Six times
Cats are expert jumpers and can leap several times their own height

18
Both cats and dogs have five toes on each front paw and four on each back paw

The newest genetically distinct cat breed is the Selkirk Rex, also known as the poodle cat

2013

BLOODHOUNDS CAN TRACK SCENTS MORE THAN 300 HOURS OLD FOR MORE THAN 130 MILES

DID YOU KNOW? Like humans, cats can have a dominant front paw

40%

Much more of a dog's brain is dedicated to smelling than a human's

98.8%

Dogs share the majority of their DNA with wolves

2.7 KILOGRAMS

The Chihuahua is the world's lightest dog breed

CATS CAN ROTATE THEIR EARS 180 DEGREES AND INDEPENDENTLY OF EACH OTHER

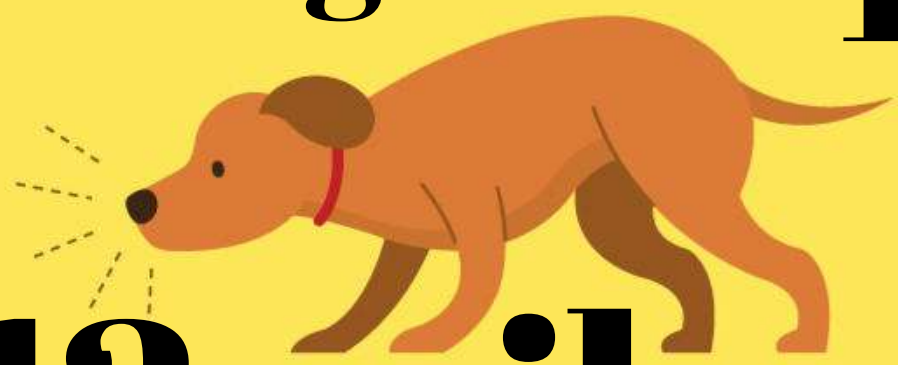
Chow Chow and Shar-Pei breeds have blue or black tongues

24

Cats typically have a dozen whiskers on each cheek

14

Only a handful of genes determine a dog's size and shape



12 miles

Dogs can smell objects and people from greater distances than the height of Mount Everest

108 kilograms

The Mastiff is the world's heaviest dog breed

CATS: 12 TO 14 YEARS DOGS: 10 TO 13 YEARS

Dogs and cats typically live for over a decade

CATS: 600 MILLION DOGS: 900 MILLION

The world population of cats and dogs is in the billions, though not all of these are pets

CATS: 76.5 MILLION DOGS: 90 MILLION

The United States has the most domestic cats and dogs

© Getty

THE OLDEST PLANTS IN THE WORLD

Discover the trees, flowers, shrubs and clonal colonies with deep roots in our planet's history

WORDS AILSA HARVEY

DID YOU KNOW? Individual trees in the Huon pine colony can reach 3,000 years old

Did you know?

Radiocarbon dating determined King Clone's age

Huon pines are endemic to Tasmania

MOUNT READ HUON PINE COLONY
10,500 years old

West Tasmania, Australia

The ancestry of the Huon pine plant family, Podocarpaceae, can be traced back to 200 million years ago through fossilised plant pollen records. But despite being called a pine, the Huon pine is actually another type of coniferous tree with scale-like leaves called a *Podocarpus* tree. In Tasmania, there's one clonal population of this tree that covers an area of 10,000 square metres. Even though it's a large population of individual trees, each one stemmed from a single male Huon pine tree that grew over 10,500 years ago. This makes the population the world's oldest colony of genetically identical trees.

Today, each of these trees is an exact replica of the original, which shed its branches and multiplied in number. After uncovering that each of the Mount Read Huon pine trees were identical in the 1990s, scientists developed a theory about how the original ancient tree lives on in others. The main theory is that its branches were weighed down by snow and ice over the course of millennia. As the branches came into contact with the ground they were able to re-root themselves and form new trees. While none of the trees are as old as the first to plant its roots here, this cloned population is essentially the same organism.

KING CLONE 11,700 years old

Mojave Desert, California

The survival abilities of creosote bushes are impressive across the board; the small, waxy-leaved shrubs are adapted to life in the most arid deserts. However, the doughnut-shaped bushes that make up the King Clone bush ring are believed to have come from one of the first life forms to thrive in the Mojave Desert, appearing shortly after glaciers covered this land. When the original plant that grew in place of this ring began to wither away thousands of years ago, its roots branched out underground and created offshoots from which new plants of the same organism could grow. Over time, these plants have expanded to form the ancient bush ring, with a diameter that reaches up to 20 metres and has an average of 14 metres.

University of California professor Frank Vasek discovered that King Clone was a single organism and estimated its age

© Shutterstock / Getty / Wikimedia Commons / Klokeid

9

3

1

9

1

4

Did you know?

The Hundred-Horse Chestnut is now a national monument

5

5

4

10

ANCIENT INDIVIDUALS

Where can you find the oldest trees in the world?

1 METHUSELAH
4,854 years old

In the White Mountains of California, a chunky bristlecone tree reaches to the sky like a twisted claw. The bends of each branch are the final remnants of the tree, which germinated before the Egyptian pyramids were built. Only a small portion remains living, and continues to bear pinecones and needles. It measures 70 metres tall and has a diameter over eight metres at ground level.

2 SARV-E ABARKUH
4,500 years old

This bushy evergreen can be found at the heart of Yazd, Iran, in the ancient city of Abarkuh. The Persian cypress tree symbolises long life and beauty in Iranian culture and is likely to be the oldest living organism on the Asian continent.

3 LLANGERNYW YEW
4,000 years old

Since the Bronze Age, this prehistoric yew tree has been growing in the rural village of Llangernyw in North Wales. The exact age of the tree is difficult to determine due to the original core trunk giving rise to newer wood. When the Celts settled in Llangernyw, they considered the tree to be sacred as it could revive itself with new bark.

4 ALERCE MILENARIO
5,480 years old

In Alerce Costero National Park, Chile, a conifer tree over 60 metres tall and with a diameter of 4.26 metres extends from a damp ravine. This ravine may be the secret to its long life, with the steep walls sheltering the tree from the elements, such as storms and fires. Scientists believe that this tree began to grow at the same time that humans started writing.

5 PATRIARCA DA FLORESTA
3,000 years old

This tropical tree, of the species *Cariniana legalis*, is a semi-deciduous tree with an umbrella-shaped top. Its name translates to ‘father of the forest’, and the tree is currently being protected by conservationists from the mass-scale deforestation that’s occurring in Brazil.

DID YOU KNOW? The tree Methuselah has a dense, resinous bark, limiting fungi and insect invasions

6 OLIVE TREE OF VOUVES
3,000 years old

This majestic olive tree appears to hover over the ground due to its exposed hollow trunk. Located in Crete, Greece, this is the world's oldest olive tree, yet it still bears fruit today. Its wood is constantly renewing outwards, forming a 4.6-metre-wide trunk for the mere 6.5-metre-tall plant.

7 JŌMON SUGI
2,170 to 7,200 years old

On the Japanese island of Yakushima is a Japanese cedar tree older than Japan itself. Material called tephra, which is produced by a volcanic eruption, has been found in the layers of the tree and is estimated to have originated from the Yakushima volcanic eruption 7,300 years ago.

8 HUNDRED-HORSE CHESTNUT
3,000 years old

If you were going to plant a long-lived tree, you might want to avoid placing it near an active volcano. However, Mount Etna in Sicily, Italy, is home to the world's largest and oldest chestnut tree. The tree has a diameter of 22 metres and is rooted less than eight kilometres from the volcano's crater.

9 GENERAL SHERMAN
2,200 years old

At 83 metres tall and with an 11-metre base diameter, General Sherman is the largest tree in the world by volume. The giant sequoia is located in California and has remained stable over thousands of years due to its widespread roots that hold onto the roots of other trees.

10 OLD TJIKKO
9,500 years old

This is the world's oldest tree, but the section that lies above the ground is only a few hundred years old and five metres tall. The spruce tree of Sweden's Fulufjället Mountain grew from the root shoots of its previous bark, which began growing just after the last ice age.

© Alamy / Shutterstock / Getty / Wikimedia commons / Sturm

Silene stenophylla has white blossoms and small seeds

ICE AGE FLOWER

32,000 years old

Kolyma River, Russia

Some of the world's oldest plants have survived across millennia. But *Silene stenophylla*, a flowering plant known commonly as the narrow-leafed campion, has the honour of being one of the world's most ancient living plants after being brought back to life. When scientists were studying the remains of an ancient squirrel burrow, inside they discovered the seeds of the narrow-leafed campion, preserved in permafrost. Permafrost is any layer of soil that remains frozen for at least two years. In this case, however, the plant's genes stayed frozen for many thousands of years at over 40 metres below Earth's surface. By germinating these seeds, the scientists brought the preserved genes to life and were able to analyse the evolution of the species with this live, historic sample.

Did you know?

Each *Welwitschia* plant only produces two leaves

KING'S LOMATIA

43,600 years old

Tasmania, Australia

There are around 300 of these plants left in existence on the planet, but some would say there's just one left. This is because the King's lomatia is a clonal group with the same genetic information. These flowering plants don't produce seeds, but shed their branches in order to reproduce identical copies through re-rooting.

The last remaining colony exists in a secret location in Tasmania in order to keep them protected. The plants of this colony have been growing in Tasmania for at least 43,600 years, but some scientists think it could be as many as 135,000. Today the King's lomatia covers a single one-kilometre strip of Tasmanian land.

King's lomatia was discovered in 1937

LOSH RUN BOX HUCKLEBERRY

13,000 years old

New Bloomfield, Pennsylvania

While covering an extensive area of Pennsylvania's forest floor, the Losh Run box huckleberry only reaches around 30 centimetres in height. The plant produces both bell-shaped flowers and dark berries that are similar to blueberries in appearance. It's the oldest known shrub colony in the world and was discovered in 1920 in Perry County, Pennsylvania. Losh Run remained a single colony until the 1970s, when a road was built to run through the area. Despite being separated, some of the oldest shrubs still remain dispersed around the area.

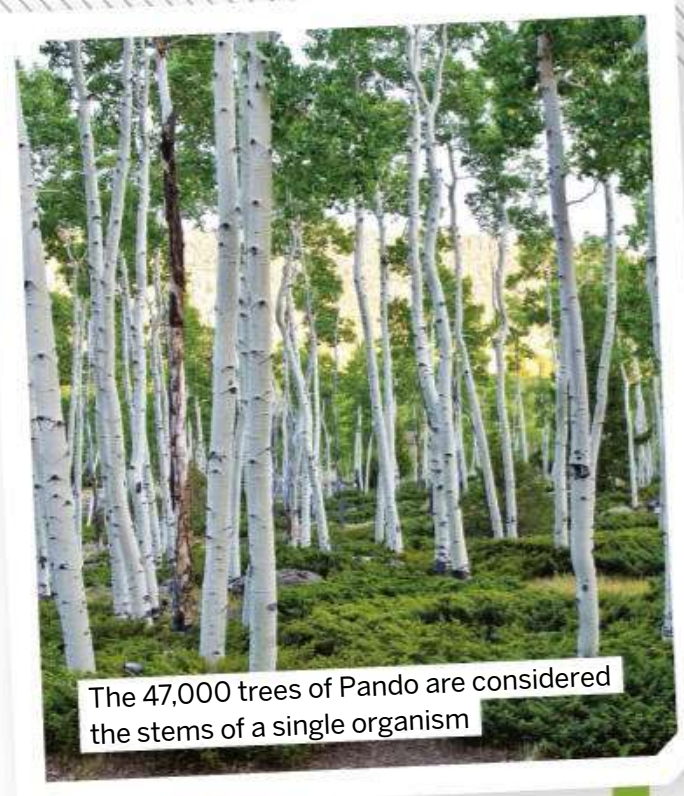
Box huckleberries bloom in May and June

PANDO, THE OLDEST LIVING ORGANISM

80,000 years

Fishlake National Forest, Utah

Comprising over 40,000 quaking aspen trees, Pando is the world’s largest organism by weight. It’s considered a single organism because Pando, which translates to ‘I spread’ in Latin, is one large root system. The forest of trees covers 429,000 square metres and has an estimated weight of 6,600 tonnes. To make new individuals in the colony, Pando releases new shoots from the existing tree roots. These eventually separate from the original tree and grow a replica, increasing the chances of the organism’s survival. This technique has allowed Pando to thrive over many thousands of years, combating forest fires and other natural disasters.



The 47,000 trees of Pando are considered the stems of a single organism

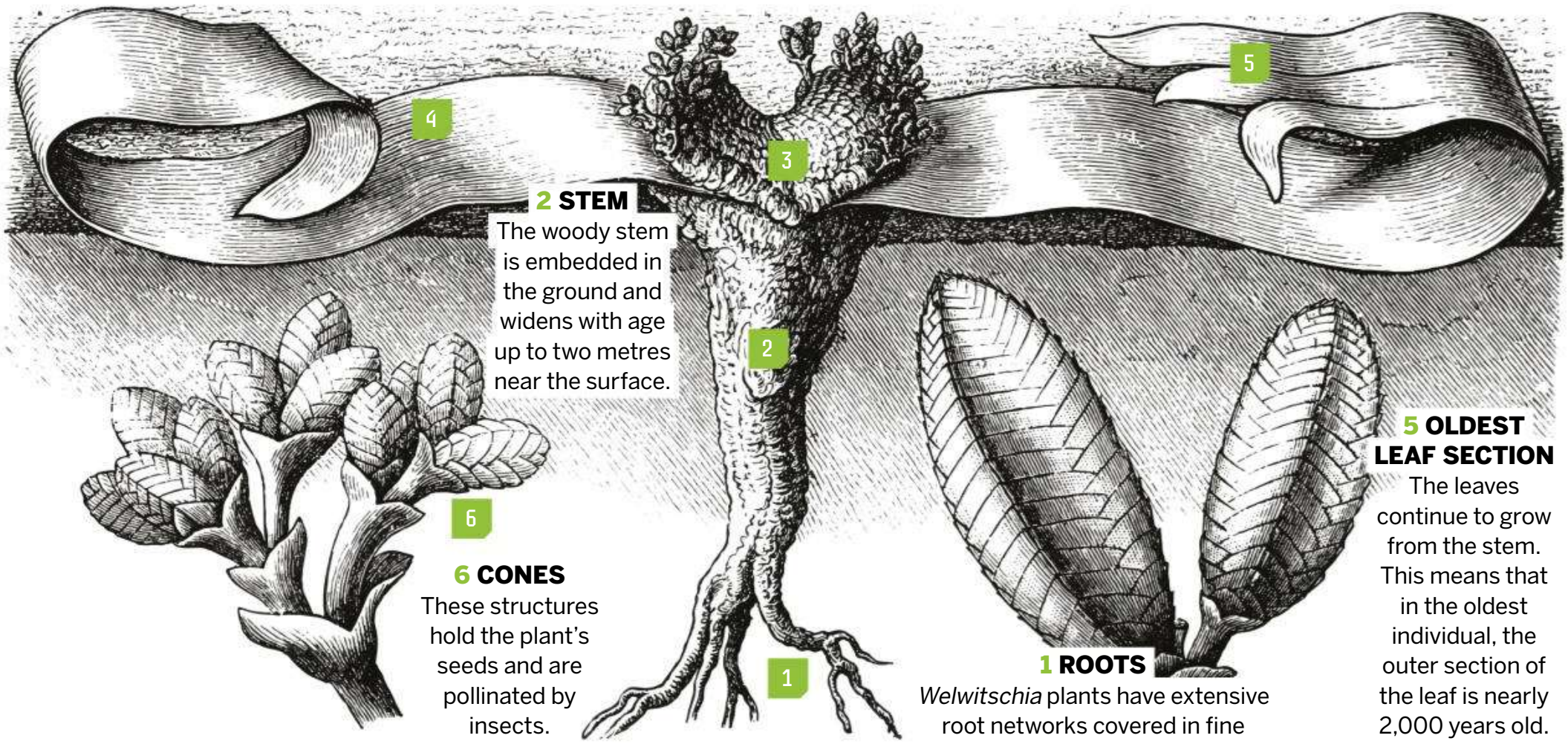
WELWITSCHIA: THE LIVING FOSSIL

This hardy 2,000-year-old plant is thought to have evolved with the dinosaurs

Namib-Naukluft Park, Namibia

4 LEAVES
Welwitschia leaves are adapted to absorb the limited water from the fog that forms in the desert during the night.

3 DEAD APEX
The top of the *Welwitschia* stem dies, preventing upward growth and causing the leaves to grow along the ground.



2 STEM
The woody stem is embedded in the ground and widens with age up to two metres near the surface.

6 CONES
These structures hold the plant’s seeds and are pollinated by insects.

5 OLDEST LEAF SECTION
The leaves continue to grow from the stem. This means that in the oldest individual, the outer section of the leaf is nearly 2,000 years old.

1 ROOTS
Welwitschia plants have extensive root networks covered in fine hairs to soak up as much water from the dry soil as possible.

© Alamy / Getty / Shutterstock / Wikimedia Commons / Hlpgtf2

HOW MARINE ANIMALS SLEEP

The ways whales, sharks and other sea creatures get a good night's sleep

WORDS **SCOTT DUTFIELD**

The world of underwater slumber is unlike what we see on the surface. For mammals, a good night's sleep sends an animal into a state of unconsciousness during hours of restorative sleeping that helps heal the body and cement memories firmly in the mind. For fish, however, 'sleep' isn't such a well-defined process. Instead, many fish species have taken to spending short periods in a state of reduced activity or rest while keeping their eyes open to scan the water for potential predators. During these periods of reduced activity, a fish's metabolic processes slow down and its alertness drops.

The breadth of animals in the ocean that exhibit this type of reduced activity is wide-reaching. Among the hundreds of thousands of creatures in the sea, some merely float along with the current, such as jellyfish. Others find rocky bedrooms for the night, while those such as stingrays bury themselves in the sand to rest. However, it must be really hard to get a good night's sleep when you breathe air but live in water. This is something that the world's marine mammals have to contend with.

To prevent themselves from drowning in their sleep, marine mammals such as dolphins and manatees have evolved the ability to 'turn off' one hemisphere of their brain to rest, known as unihemispheric sleep. While one hemisphere is fast asleep, the other keeps all the animal's vital functions running, such as breathing. Manatees, for example, love to sleep, spending up to 12 hours a day in a deep doze. However, as air-breathing animals, manatees need to surface every 20 minutes or so for oxygen. To achieve this, the half of the brain that's still awake sends the snoozing manatee to the surface to get some air.

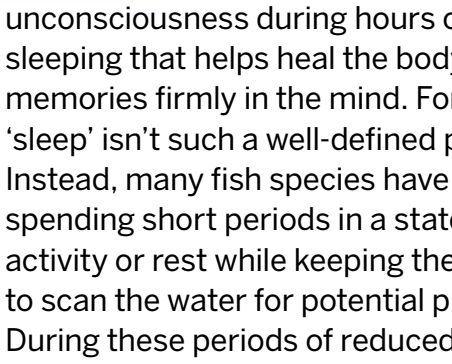
A parrotfish tucking up in its mucus pest-control duvet for the night

MUCUS DUVETS

When the Sun sets and it's time for parrotfish (*Chlorurus*) to settle in for the night, they swim down to the seafloor and find a nice spot among the rocks to sleep. Having found somewhere to rest, these vibrant tropical fish secrete mucus from glands behind their gills that form a cosy cocoon around the entire fish. The snotty duvet takes about 30 minutes to make, but surrounds the parrotfish for the whole night. In the same way that a mosquito net protects you during the night, a parrotfish's mucus cocoon protects the fish from blood-sucking parasites called Gnathiidae isopods. Along with being a physical barrier, the cocoon also locks in the fish's scent, preventing other animals from sniffing it out while it sleeps.

SPERM WHALE SLUMBER PARTY

How these ocean giants spend some of their time sleeping vertically



STAYING AFLOAT
A waxy substance in the head cavity called the spermaceti helps keep sperm whales buoyant while they sleep.

DEEP SLEEPER
These whales snooze around 20 metres below the water's surface.

POWER NAP
Sperm whales don't sleep for long; they rest one half of their brain at a time for only 10 to 15 minutes.

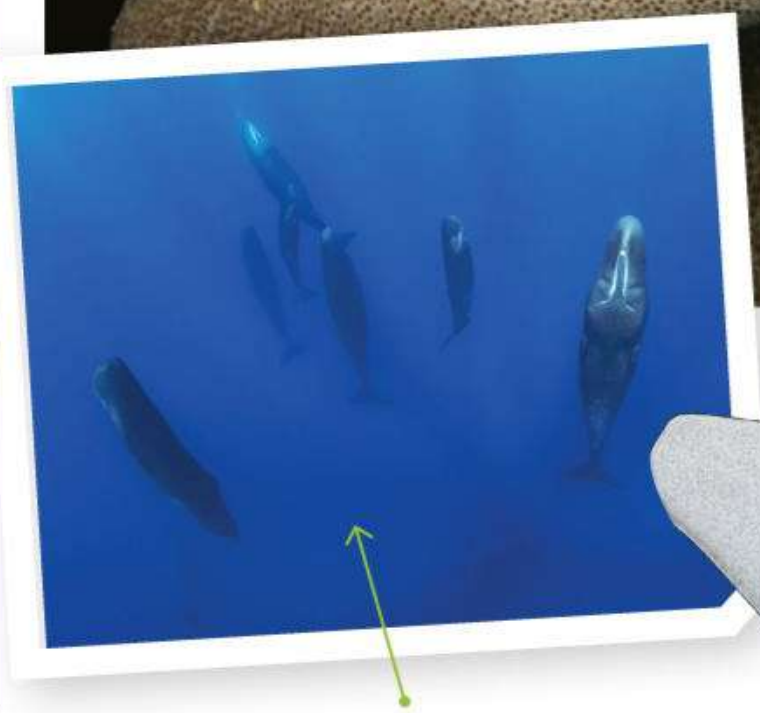
DID YOU KNOW? At night, clownfish snuggle between the stinging tentacles of anemones to sleep

OCTOPUS DREAMS

Since most fish aren't fully unconscious when they sleep, it's safe to assume that dreaming is a rarity underwater. However, researchers have discovered a short window where an octopus' mind might drift off to dreamland. Octopus subjects were observed to have cycles of sleep that included elongated moments of peaceful rest and short bursts of activity. For humans, these short bursts might be comparable to tossing and turning, but octopuses' skin changed colour and tentacle suckers contracted. For around 40 seconds at a time, octopuses changed their skin colour and texture, suggesting they might be having short, simple dreams that are triggering these changes.

Perhaps this octopus is dreaming of catching a tasty crab

An African Blenny sleeping in the contours of a smooth coral



GROUP SNOOZE
Clusters of whales, known as a pod, sleep together in groups of five or six.

UPRIGHT
Around seven per cent of a sperm whale's sleeping time is spent in a vertical position.

OPTIMAL OXYGEN
Sperm whales absorb around 90 per cent of the oxygen in each breath to keep their organs filled with oxygen-rich blood while they sleep.

Did you know?

Humpback whales can sleep for up to 30 minutes at a time

A pair of manatees taking a nap on the seafloor

© Alamy / Getty / Science Photo Library

HOW FOG FORMS

When water vapour turns to liquid, a murky mass fills the air

WORDS **AILSA HARVEY**

Most of the time, clouds hover far above our heads at high altitude. In these colder conditions, the air loses the ability to hold onto water vapour and releases droplets of liquid water. Although it forms in a similar method to clouds, fog extends into lower altitudes and can lie just above the ground. Fog forms when the air's water vapour content is high and conditions are humid. Being close to the ground, the water-filled air reduces visibility and limits the navigation of cars, ships and aircraft. The extent of fog disruption depends on the concentration of water droplets in the air, with the thickest fog usually arising under contrasting conditions, where cold air meets warm air. The foggiest place on the planet is an area of the Atlantic Ocean called Grand Banks, where the northern Labrador Current comes into contact with the warmer Gulf Stream.

MISTY BUSINESS

Fog and mist appear very similarly in the air as small water droplets that reduce visibility. It's how much the suspended water impacts visibility that determines whether it's classified as fog or mist – fog is thicker than mist. When saturated air prevents you from seeing as far as 1,000 metres, the term 'fog' is used to describe it. If it's possible to see objects at least 1,000 metres in the distance then it is referred to as mist. When walking through foggy air, you will emerge much damper than when travelling in mist.

Fog reduces aircraft takeoff rates at airports due to severely reduced visibility

A 40-square-metre fog catcher can capture up to 66 litres in one day

CLOUD HARVEST

When water is suspended in the air in the form of fog, it becomes easier to capture than when it has landed on the ground and seeped through the soil. But to effectively harvest water from foggy landscapes, fog catchers are required. Fog catchers are large screens that are usually assembled in regions with less rainfall. When fog-filled air blows over these screens, the mesh panels catch the water as it condenses, allowing it to drip into containers below. In regions with no local rivers, lakes or glaciers, these screens mean water can be collected on-site rather than having to be imported.

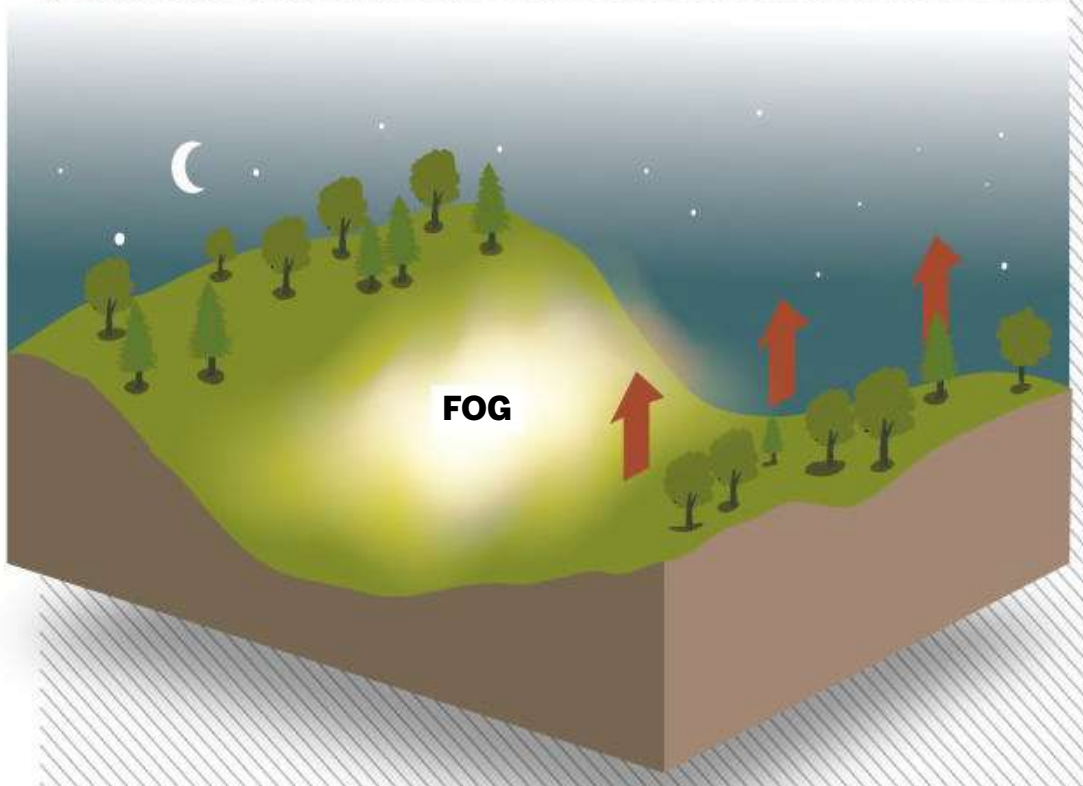
DID YOU KNOW? Atrapaniebla Brewery in Chile uses fog water from the desert to brew its beer, called Fog Beer

HAZY DAYS

Different environments can lead to diverse forms of this low-lying cloud

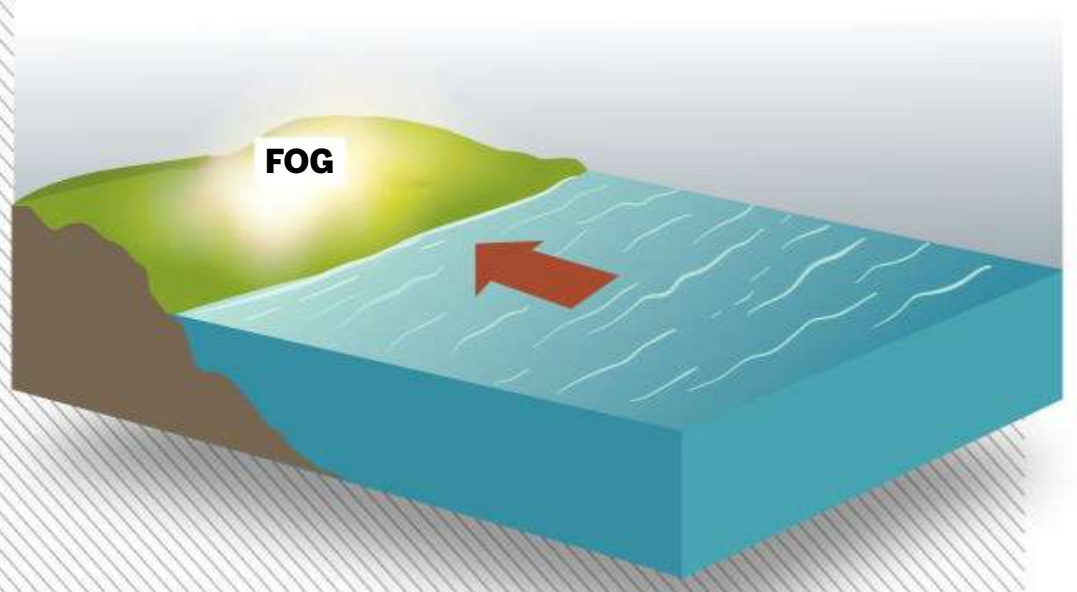
Did you know?

Fog creates the illusion that you're driving slower



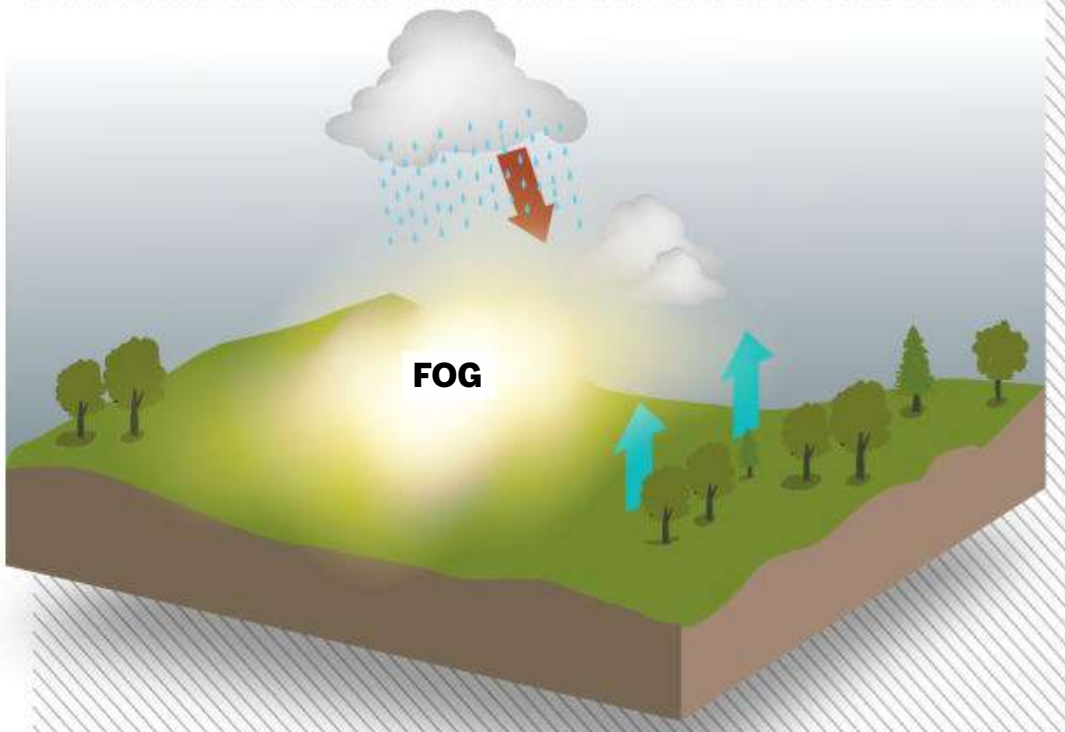
RADIATION FOG

This type of fog forms during mild weather, when there is little wind and the skies are clear of other clouds. The lack of cloud coverage enables Earth's surface heat to escape towards space. The air near the ground cools and condenses into a layer of fog, which grows overnight as the air cools further. When the Sun heats the air again the following day, the fog dissipates.



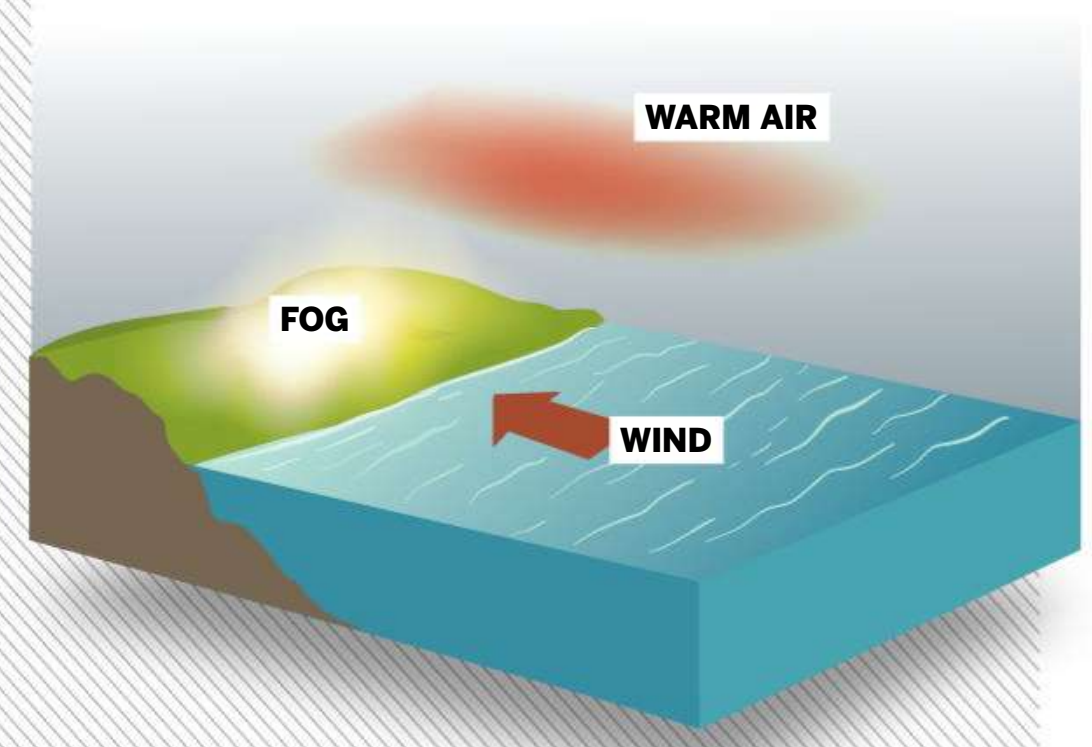
ADVECTION FOG

Advection fog forms in a similar way to radiation fog, but is caused by warm air moving horizontally over colder air rather than the vertical loss of surface heat. When the warm air approaches colder ground, it becomes saturated and forms fog.



FRONTAL FOG

This fog is formed when raindrops evaporate in the air. The rain falls through warmer air into cold stable air and forms a fog layer near the ground. When enough rain has saturated the cold layer of air, foggy clouds become visible.



SEA FOG

Warm and moist air that forms over a body of water becomes cooler as it's transported with the wind. This cooling causes sea fog to form. When it reaches the warmer air above land it may begin to dissipate.

© Alamy / Getty / Shutterstock

The future of SPACE TRAVEL

Discover possible future spaceship technologies, from the practical to the far-fetched

WORDS **ANDREW MAY**

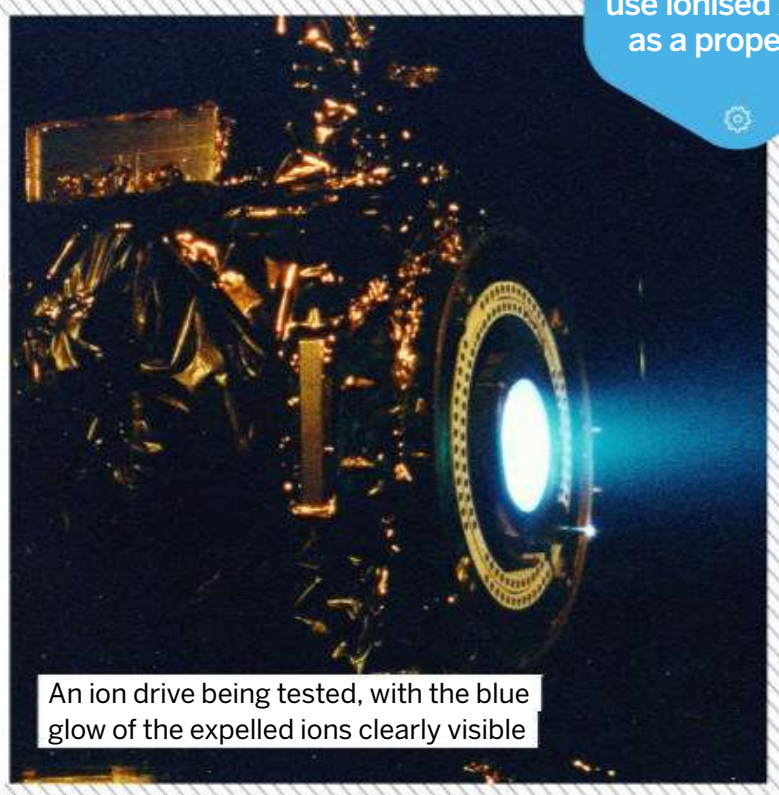
DID YOU KNOW? Ion drives only produce a very gentle thrust, but it can be kept up continuously throughout a mission

ION DRIVE

STATUS: **TESTED IN SPACE**
RANGE: **INTERPLANETARY**

A conventional rocket works by expelling exhaust gases from a combustion reaction through a rear-facing nozzle, resulting in a forward thrust via the conservation of momentum. An ion drive also generates thrust by expelling material, but in this case it's a stream of ions – atoms that have had electrons stripped off to create a positive electric charge. Before being ejected, these ions are accelerated to high speeds using an electric field. The energy to maintain this field – as well as that needed to ionise the propellant atoms – comes from solar panels. For this reason, ion drives are sometimes referred to as solar-electric propulsion. Ion drives powerful enough to propel a crewed spacecraft still lie in the future, but NASA has used them in some of its smaller interplanetary probes, such as the Dawn mission to the asteroid belt and the Double Asteroid Redirection Test, which slammed into an asteroid last year.

Did you know?
NASA's ion drives use ionised xenon as a propellant



An ion drive being tested, with the blue glow of the expelled ions clearly visible

MACH-EFFECT DRIVE

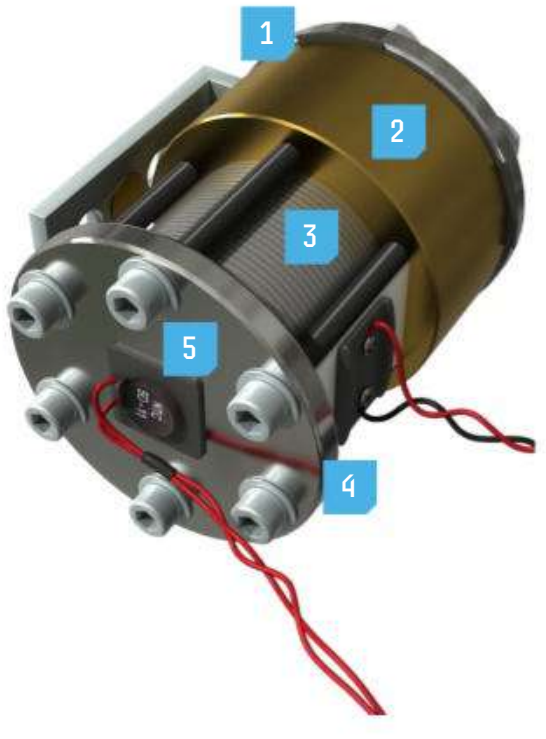
STATUS: **SPECULATIVE**
RANGE: **INTERSTELLAR**

Propulsion systems such as rockets and ion drives work by the conservation of momentum, ejecting propellant in one direction to produce thrust in the opposite direction. This means that their range is always limited by the amount of propellant they can carry. But a few scientists believe in 'reactionless' space drives that don't conserve momentum, and hence don't need any propellant. One such drive, proposed by James Woodward of the Space Studies Institute, uses what he calls the 'Mach effect', which draws on the ideas of a 19th-century philosopher named Ernst Mach. Most academic physicists believe that Woodward's space drive is unworkable, but he claims to have tested it in a laboratory and is seeking further research funding from NASA. If the system works in the way that Woodward hopes, he says it could power a probe all the way to the nearest known exoplanet, Proxima b.

Artist's impression of an interstellar space probe based around a hypothetical Mach drive

TESTING A REACTIONLESS DRIVE

Conventional physics says reactionless motion is impossible, but here's how a Mach drive might work



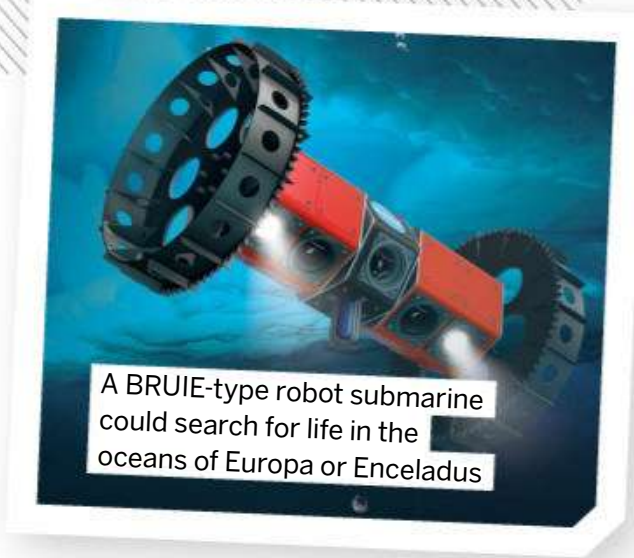
1 LABORATORY PROTOTYPE
A small test thruster demonstrates that the basic principle works before scaling up.

2 CONSTANT MASS
The test thruster contains a solid brass foundation of constant mass, standing in for the body of a real spaceship.

3 VARIABLE MASS
This stack of piezoelectric discs acts as both the source of mechanical movement and the varying reactive mass.

4 VIBRATIONS
Because piezoelectric material expands when electrified, this will cause the whole stack to vibrate against the brass foundation.

5 REACTIONLESS THRUST
Using the controversial concept of 'variable mass', the device produces a forward thrust without expending propellant.



A BRUIE-type robot submarine could search for life in the oceans of Europa or Enceladus

UNDER-ICE EXPLORER

STATUS: **RESEARCH PROJECT**
RANGE: **PLANETARY OCEAN**

If there's life in the Solar System, many scientists believe it's most likely to be found on one or more of the icy moons of the giant outer planets. This wouldn't be on the icy surface itself, but in the large, liquid-water ocean that's believed to lie beneath. The most direct way to test this theory is by exploring those oceans with a robotic submarine – and that's just what a vehicle currently being developed at NASA's Jet Propulsion Laboratory is. Called BRUIE, which stands for Buoyant Rover for Under-Ice Exploration, it's initially intended for research in ice-covered seas on Earth, but it could easily be adapted for use on a future mission to an icy moon like Europa or Enceladus, where it could search for signs of life at the ice-water boundary.

© Alamy / Getty / NASA

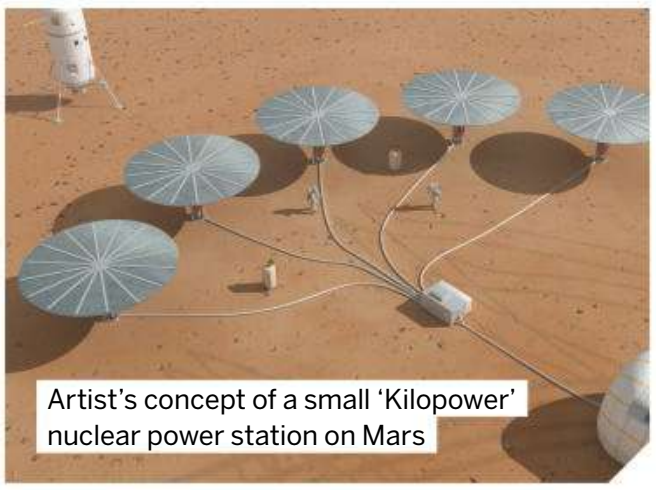
The atmosphere on Mars is thin enough that a vacuum-filled airship might be feasible

VACUUM AIRSHIP

STATUS: **NASA PROPOSAL**

RANGE: **PLANETARY ATMOSPHERE**

On Earth, an airship floats because it's filled with a lightweight gas like hydrogen or helium. Theoretically, an even more efficient airship could be built if it was filled with nothing at all – a complete vacuum. That's not possible on Earth because of atmospheric pressure. On Mars, on the other hand, where the atmosphere is much thinner, such a design might be possible, and NASA scientists have proposed building such a vacuum-filled airship.



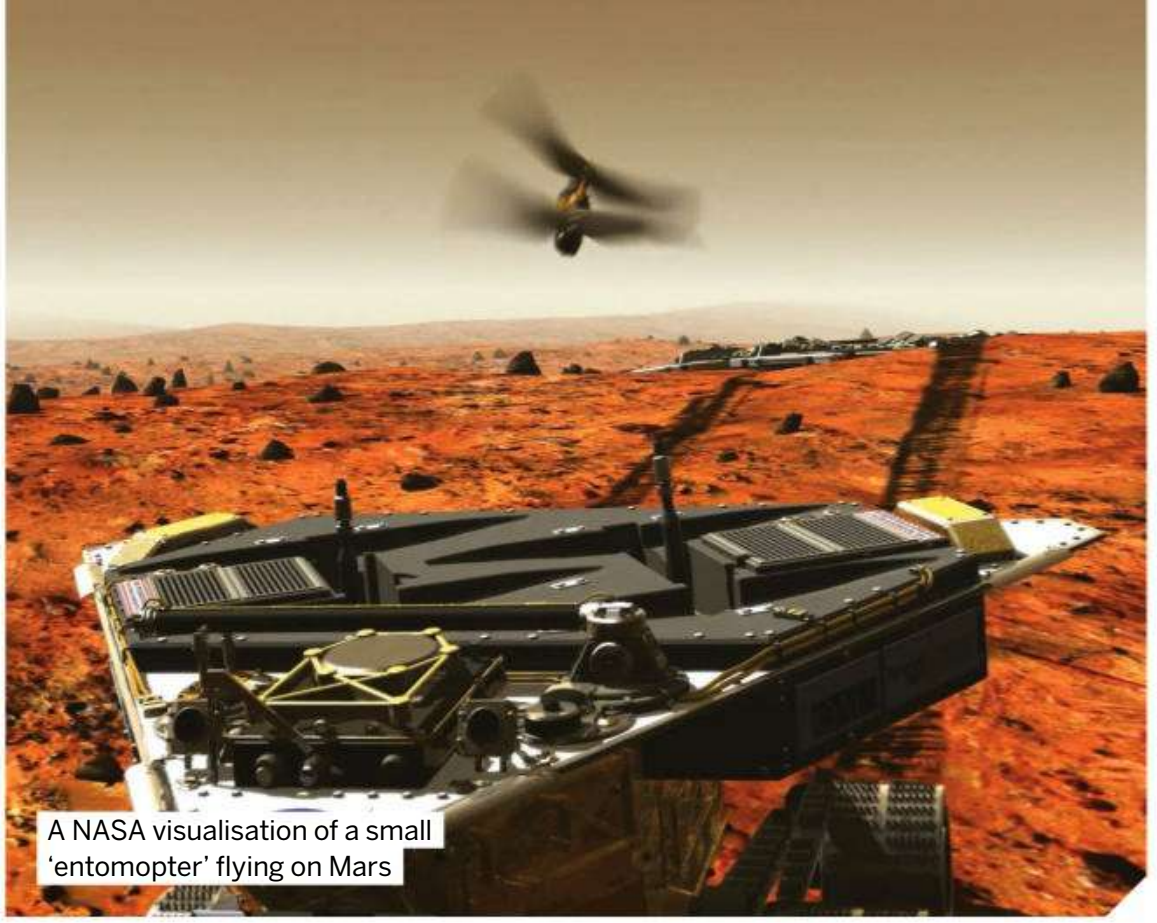
Artist's concept of a small 'Kilopower' nuclear power station on Mars

SUPPORT TECH: MARS POWER STATION

STATUS: **RESEARCH PROJECT**

RANGE: **N/A**

Any future settlement on Mars will require a source of electrical power, and the most compact solution would be a small nuclear power station. The Kilopower project team at the US Department of Energy's Los Alamos National Laboratory's proposed solution employs a heat pipe running around the reactor to circulate hot fluid to a device called a Stirling engine. This uses the heat to pressurise a gas and drive a piston, powering an electrical generator.



A NASA visualisation of a small 'entomopter' flying on Mars

FLAPPING WINGS ON MARS

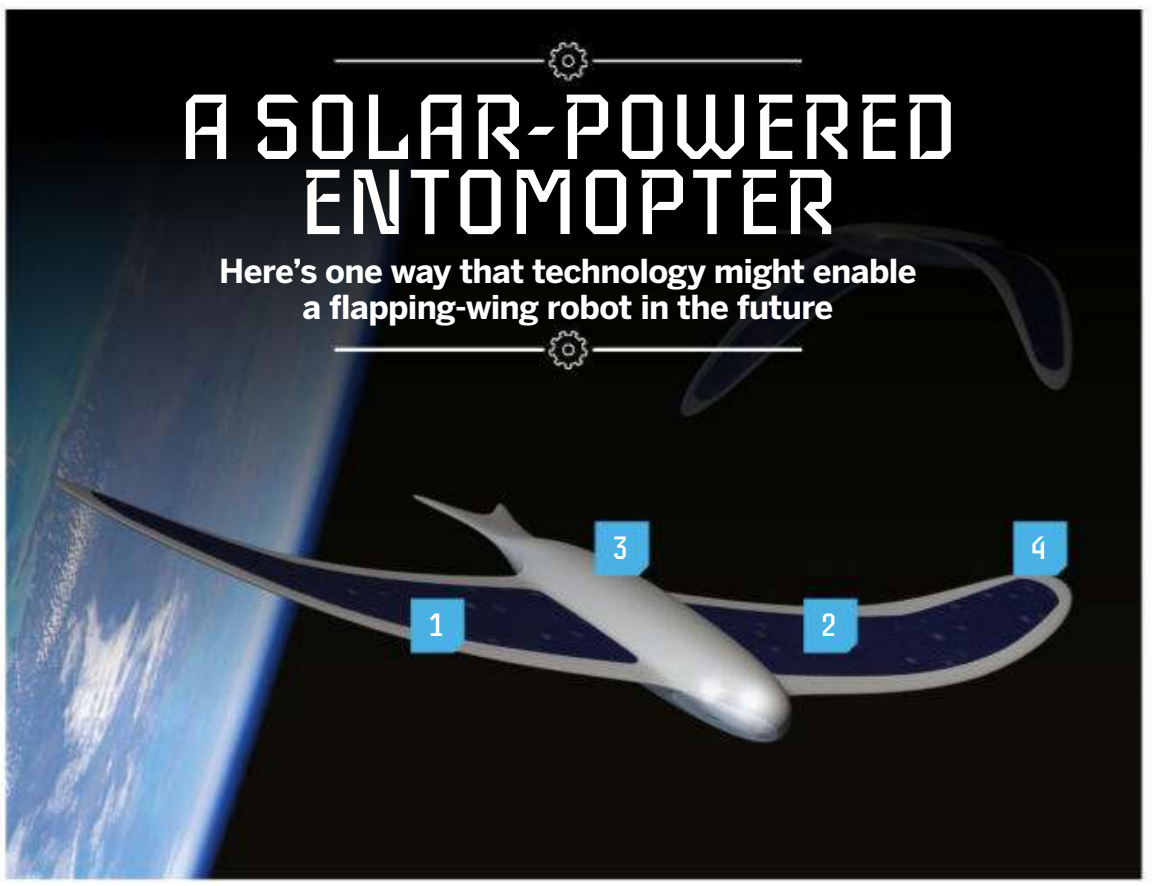
STATUS: **RESEARCH PROJECT**

RANGE: **PLANETARY ATMOSPHERE**

We've already seen Ingenuity flying on Mars, but what about an entomopter? That's the technical term for a robotic vehicle that flies by flapping its wings like an insect. Theoretical studies have shown this to be an ideal way of flying in the thin atmosphere and low gravity of the Red Planet. NASA recently allocated research funding to a team working on 'Marsbees', which one team member, Chang-kwon Kang, described as "robotic flapping-wing flyers of a bumblebee size". The idea is that the tiny robots would operate in swarms, using a surface rover as a charging point and communications hub while observing their environment with miniaturised sensors.

A SOLAR-POWERED ENTOMOPTER

Here's one way that technology might enable a flapping-wing robot in the future



1 FLEXIBLE WINGS
An ionic polymer-metal composite can display muscle-like behaviour under an applied voltage.

2 SOLAR PANELS
These provide all the electrical power for the wings and payload.

3 PAYLOAD
This could include a range of environmental sensors to study the atmosphere and surface of the planet.

4 COLLAPSIBLE DESIGN
The construction means that the structure can be folded up into a very small volume for transportation.

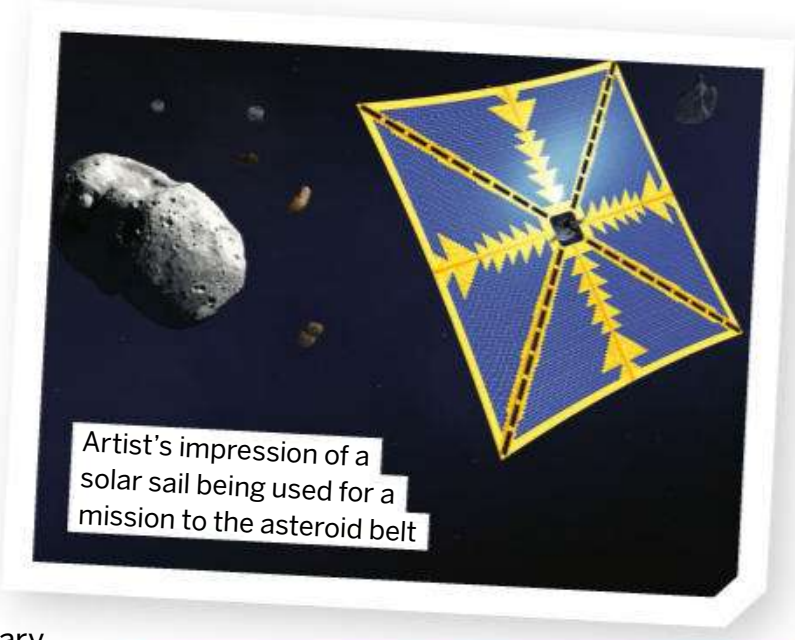
DID YOU KNOW? The Apollo astronauts were exposed to harmful radiation on the Moon

SOLAR SAIL

STATUS: **TESTED IN SPACE**
RANGE: **INTERPLANETARY**

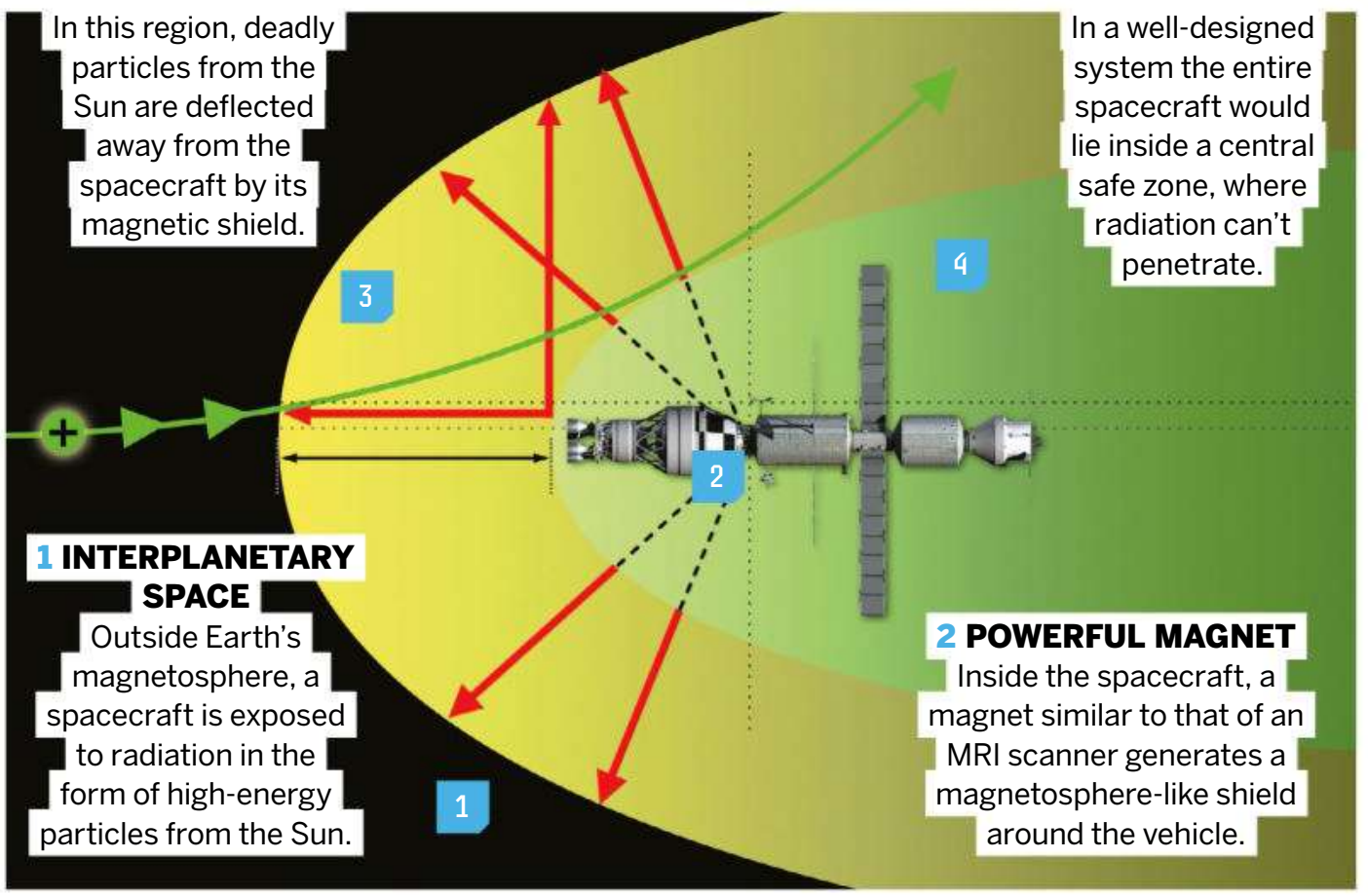
Speculative physics like the Mach effect aside, there's only one way that a ship can be driven through space without expending any propellant and still obey the law of conservation of momentum, and that's if it acquires its additional momentum from an external source – the same way that a sailing ship on Earth gets its momentum from the wind. Within the boundaries of the Solar System there's an endless – and completely free – source of momentum in the form of the photons of light streaming out from the Sun. In theory it's possible for a spacecraft to pick up this momentum using a solar sail: a large piece of lightweight fabric with a highly reflective surface to bounce the photons off.

Although not used for a serious interplanetary mission yet, the basic principle has been demonstrated in Earth orbit by the Planetary Society, whose LightSail 2 spacecraft successfully flew between June 2019 and November 2022.


Artist's impression of a solar sail being used for a mission to the asteroid belt

MAGNETIC DEFLECTOR SHIELD

Astronauts could be protected from deadly radiation by an artificially generated shield around their spaceship


3 BOW WAVE
In this region, deadly particles from the Sun are deflected away from the spacecraft by its magnetic shield.
4 SAFE ZONE
In a well-designed system the entire spacecraft would lie inside a central safe zone, where radiation can't penetrate.
1 INTERPLANETARY SPACE
Outside Earth's magnetosphere, a spacecraft is exposed to radiation in the form of high-energy particles from the Sun.
2 POWERFUL MAGNET
Inside the spacecraft, a magnet similar to that of an MRI scanner generates a magnetosphere-like shield around the vehicle.
1
2
3
4

SUPPORT TECH: MINI-MAGNETOSPHERE

STATUS: **RESEARCH PROJECT**
RANGE: **N/A**

Did you know?
A solar sail could reach Neptune in under three years

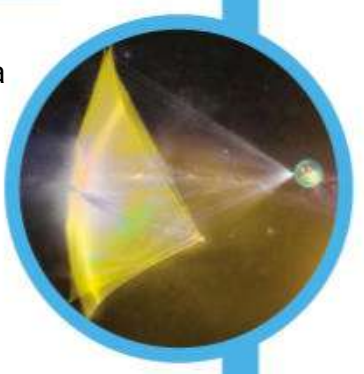
Fortunately for us, Earth's magnetic field creates a protective shield around the planet called the magnetosphere. This deflects the harmful radiation coming from the Sun in the form of high-energy charged particles. Spacecraft close to Earth also lie within the magnetosphere, like the International Space Station. Once a ship is in interplanetary space, it no longer has this shield and the crew will need some other form of radiation protection. Researchers at the UK's Rutherford Appleton Laboratory are looking at the possibility of creating an artificial 'mini-magnetosphere' around the ship to serve this function.

FOUR CRAZY-BUT-TRUE PROPOSALS

PROJECT ORION

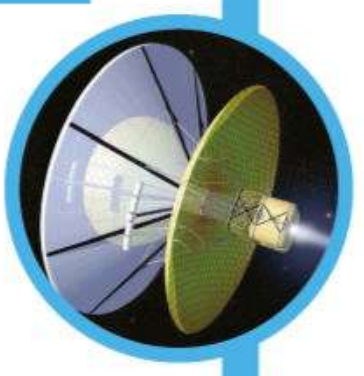
This research project, which actually saw some hardware testing by General Atomics in 1959, considered powering a deep-space mission by exploding a series of nuclear bombs behind it.

BREAKTHROUGH STARSHOT



This proposal involves a fleet of tiny spacecraft on a flyby mission to Alpha Centauri using light sails powered not by the Sun but by a super-powerful laser beam.

BUSSARD RAMJET

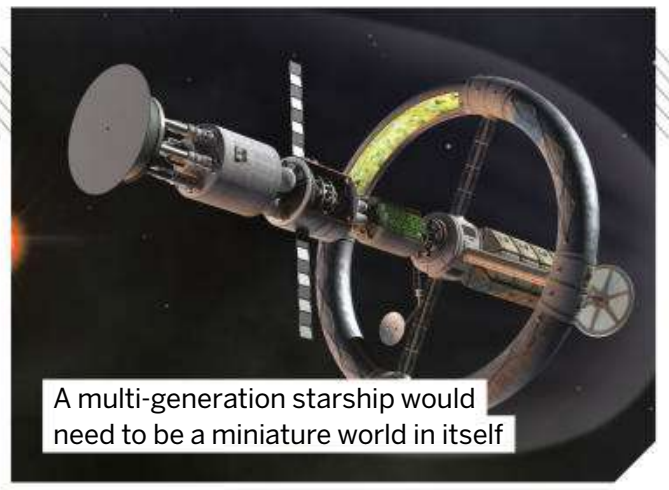


Proposed in 1960 by physicist Robert W. Bussard, this scientifically feasible interstellar propulsion system would be fuelled by the ultra-tenuous gas that permeates space.

SPACE ELEVATOR

This grandiose concept, which is being researched by several groups around the world, would see an elevator cable stretching all the way from Earth's surface to a geostationary satellite.

© Alamy / NASA / Breakthrough Starshot



A multi-generation starship would need to be a miniature world in itself

GENERATION SHIP

STATUS: **THEORETICAL**

RANGE: **INTERSTELLAR**

A craft heading for another star system will take several centuries to reach its destination. This inevitably means that its passengers will go through many generations that are born, live and die during the trip. The possibility of a multi-generation starship was discussed early in the 20th century by spaceflight pioneers Robert Goddard and Konstantin Tsiolkovsky, and has subsequently featured in numerous science-fiction stories.

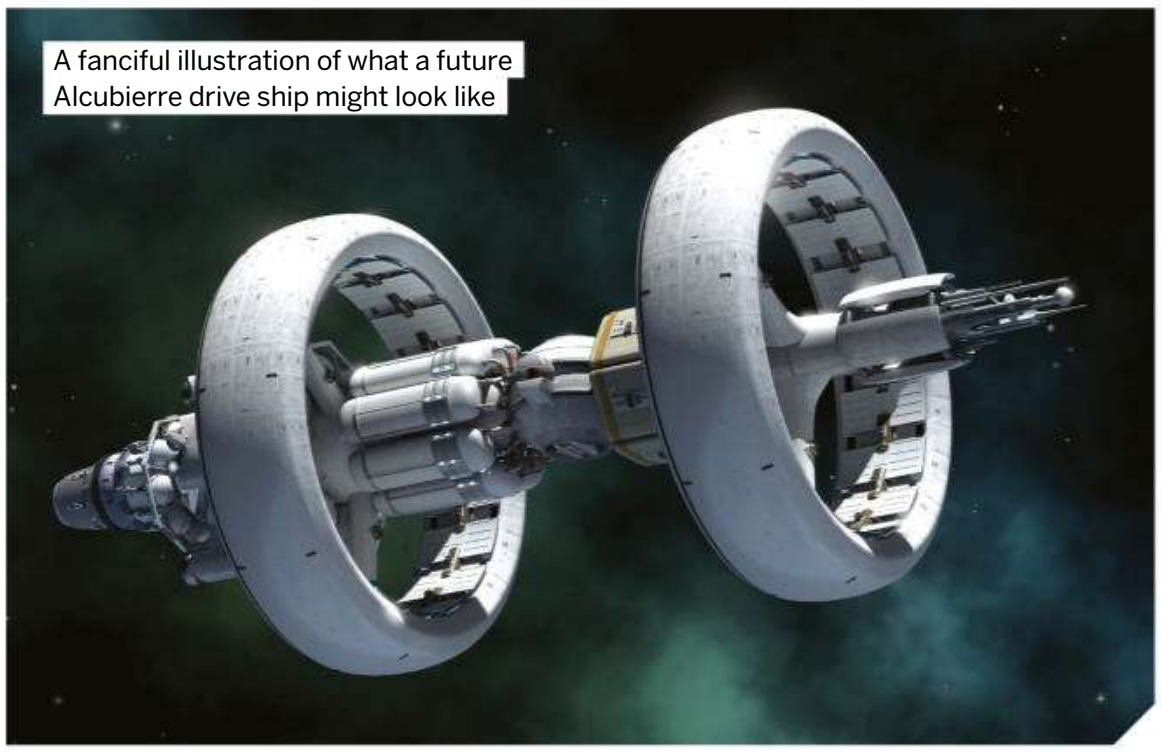
Von Braun station would spin on its axis to produce artificial gravity at its circumference

VON BRAUN STATION

STATUS: **PROPOSAL**

RANGE: **N/A**

Wernher von Braun is best known as a rocket designer, but in the 1940s and 1950s he envisioned a giant wheel-shaped space station in Earth orbit. This would spin on its axis to provide artificial gravity, with centrifugal force pressing people against the wheel's outer rim much as gravity presses us against Earth's surface. In 2019, a private organisation called the Gateway Foundation proposed building a luxury orbiting hotel of similar design, which they appropriately refer to as Von Braun Station after the man who conceptualised the idea.



A fanciful illustration of what a future Alcubierre drive ship might look like

ALCUBIERRE DRIVE

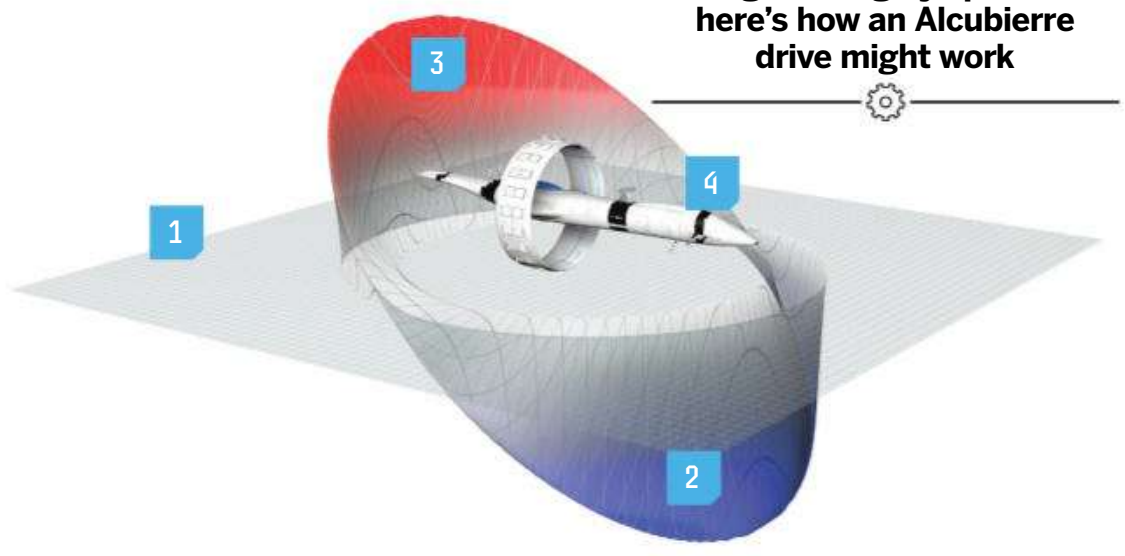
STATUS: **SPECULATIVE**

RANGE: **INTERSTELLAR**

According to Einstein's theory of general relativity, the underlying structure of space and time can be distorted – or warped – by a strong gravitational field. It was likely with this in mind that the creators of *Star Trek* used the term 'warp drive' for a starship's propulsion system in the 1960s, but it wasn't until 1994 that physicist Miguel Alcubierre showed how such a drive might actually work. His idea was to create a mechanism that would distort the fabric of space-time in such a way that the space ahead of the ship would contract while the space behind it expands. This would produce a 'warp bubble' in which the ship is pushed along through an otherwise undistorted space. Alcubierre showed such a mechanism to be possible in theory, although it's so fraught with engineering problems that it's unlikely that anyone will ever be able to build one.

A REAL WARP DRIVE

Although it's highly speculative, here's how an Alcubierre drive might work



1 UNDISTORTED SPACE
For simplicity, ordinary three-dimensional space can be pictured as a flat two-dimensional sheet.

2 COMPRESSED SPACE
The space ahead of the ship is distorted in such a way that it shrinks.

3 EXPANDED SPACE
To balance the compressed space ahead of the ship, the space behind it expands.

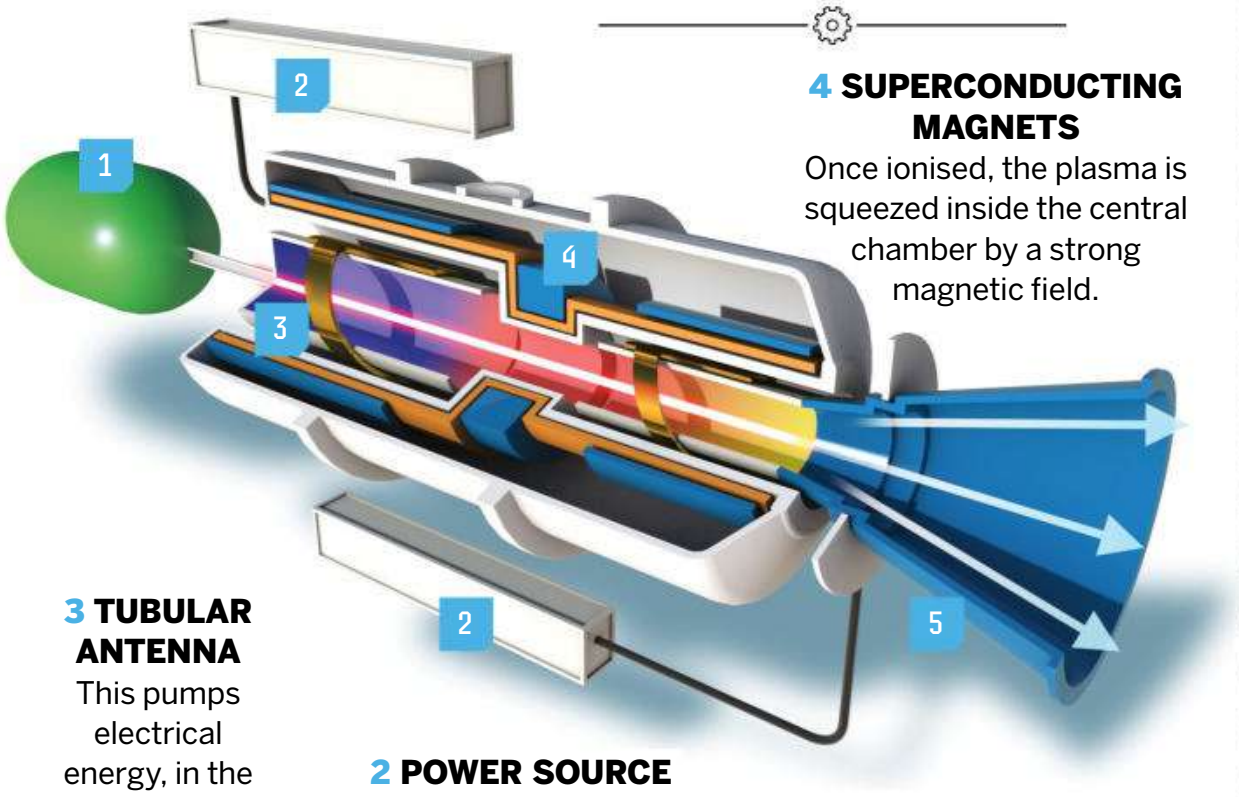
4 SPACESHIP
The ship effectively remains stationary inside its 'warp bubble', but the bubble itself is pushed forwards at high speed.

DID YOU KNOW? A 76-metre-diameter space station rotating three times a minute would produce a third of Earth's gravity at its rim

INSIDE THE PLASMA ROCKET

Drawing on 25 years of research by Ad Astra, this is how VASIMR would work

1 PROPELLANT TANK
This would typically be an inert gas like argon or xenon, stored in neutral form prior to ionisation.



4 SUPERCONDUCTING MAGNETS
Once ionised, the plasma is squeezed inside the central chamber by a strong magnetic field.

3 TUBULAR ANTENNA
This pumps electrical energy, in the form of radio waves, into the propellant to ionise it.

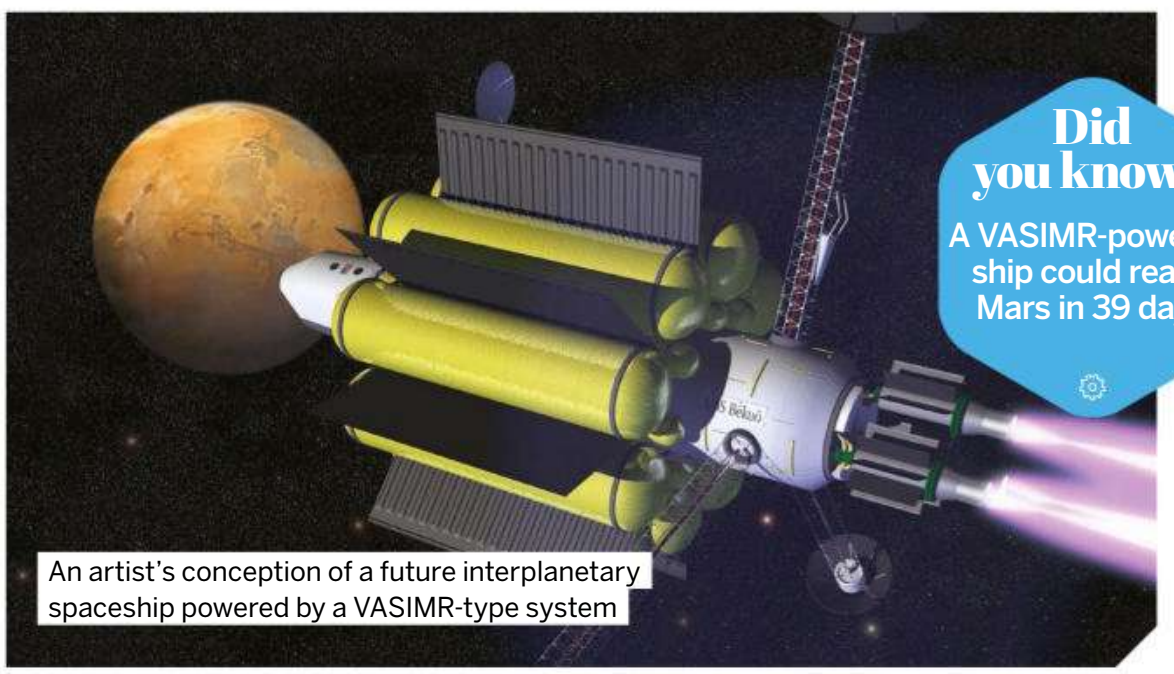
2 POWER SOURCE
Either solar or nuclear power could be used to generate electricity, depending on the amount needed.

5 MAGNETIC NOZZLE
After being heated to a high temperature, the plasma is ejected from the back of the engine to produce thrust.

VASIMR

STATUS: **UNDER DEVELOPMENT**
RANGE: **INTERPLANETARY**

VASIMR is a spacecraft engine under development by the Ad Astra Rocket Company. It stands for Variable Specific Impulse Magnetoplasma Rocket; it's comparable to an ion thruster insofar as it uses electricity as the main energy source, although its mode of operation is different. It starts in the same way by ionising a gas, but instead of using just positively charged ions as the propellant it employs a neutral plasma containing both positive ions and electrons. This is channelled through a magnetic field and ejected at high speed to provide a much greater thrust than a standard ion drive. Using either solar panels or a nuclear reactor to generate electricity, VASIMR could power a wide range of space vehicles, from small robotic spacecraft to much larger human-crewed ones, including deep-space missions to Mars and beyond.

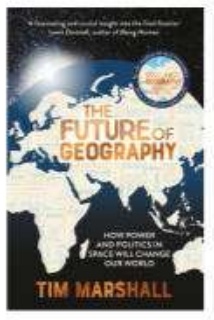


An artist's conception of a future interplanetary spaceship powered by a VASIMR-type system

Did you know?
A VASIMR-powered ship could reach Mars in 39 days

COLONISING SPACE

Tim Marshall is the author of *The Future of Geography: How Power and Politics in Space Will Change Our World*



Is a second Space Race already happening?
Definitely. There are similarities to the previous one, but it's different. In the 1960s and 1970s the Soviets and Americans were each trying to demonstrate that their technology was superior to the other as part of proving their political systems were superior. There's an echo of that now with China and the US, but it's much less ideological and less pronounced. The new race is driven by commercial prospects and military planning. No great power can allow another to be the only one trying to gain the potential advantages of mining the Moon, nor of militarily dominating space.

When space technology allows us to more easily explore and colonise other planets, do you envisage an orderly division of territories backed by international agreements?
Unless and until the outdated existing international agreements on space are completely overhauled and made relevant to the 21st century, it will be a land grab by individual powers and/or blocs. The Artemis Accords have a clause talking about 'safety zones'. Fine, the 20 signatories could agree on one, but why should the other 173 countries? Starlink's terms and conditions for service on Mars say any disputes "will be settled through self-governing principles". Frontier America? For Texas 1836 read Mars 2086.

How will we progress to exploring our galactic locale?
2030 looks ambitious, but ten years from now could be possible. During this period the Chinese and possibly the Russians will show up. Both blocs will have basic Moon bases and commercial activities up and running by the late 2030s. By then China and SpaceX may well have sent crewed missions to Mars, but Elon Musk's original idea of a million people living there by 2050 looks completely unrealistic.

© Elliot & Thompson

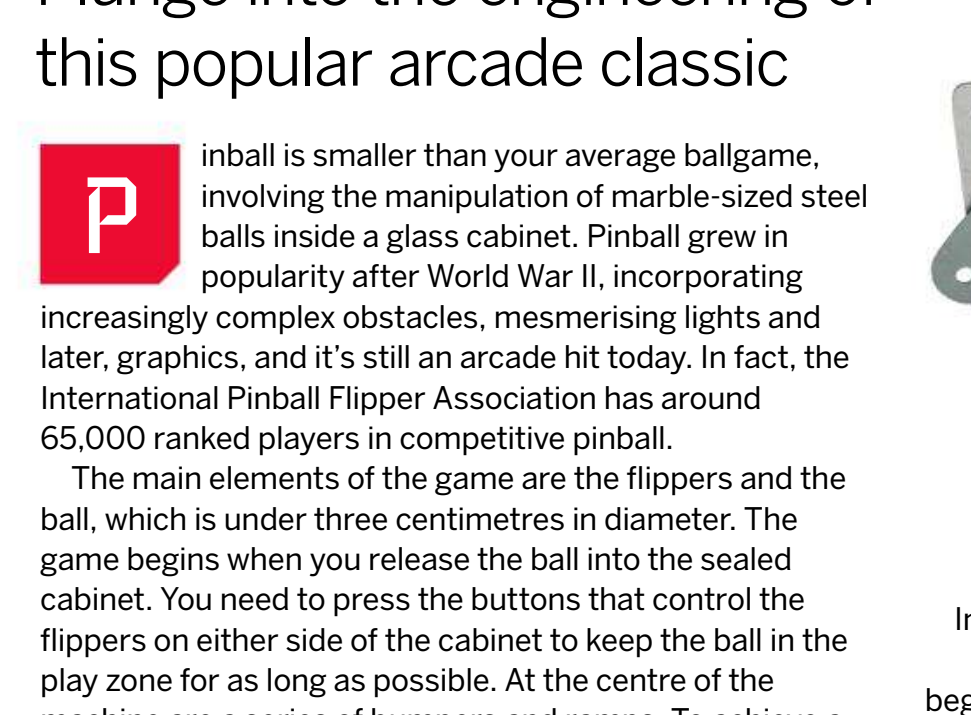
INSIDE A PINBALL MACHINE

WORDS **AILSA HARVEY**

Plunge into the engineering of this popular arcade classic

Pinball is smaller than your average ballgame, involving the manipulation of marble-sized steel balls inside a glass cabinet. Pinball grew in popularity after World War II, incorporating increasingly complex obstacles, mesmerising lights and later, graphics, and it's still an arcade hit today. In fact, the International Pinball Flipper Association has around 65,000 ranked players in competitive pinball.

The main elements of the game are the flippers and the ball, which is under three centimetres in diameter. The game begins when you release the ball into the sealed cabinet. You need to press the buttons that control the flippers on either side of the cabinet to keep the ball in the play zone for as long as possible. At the centre of the machine are a series of bumpers and ramps. To achieve a higher score, the aim is to fling the ball towards these mechanisms for bonus points. Usually, you're provided with three balls per play. When all of these balls have fallen into the drain at the bottom of the board, the game is over and your final score is displayed. Whether it's played competitively, stumbled upon in the corner of a cafe or enjoyed periodically at amusement arcades, pinball still captures people's attention almost a century since it first hooked them in the 1930s.



Two children playing with a miniature pinball machine in 1955

5 DISPLAY PANEL
This displays the score of the player after the ball comes into contact with the machine's target areas.

4 BALL LAUNCHER
An electronic button can be pressed in place of a plunger to return the ball to the top of the machine. This uses similar electronics to the flippers, pulling the metal component forcefully upwards to launch the ball.

7 COIN SLOTS
Inserting a coin into the machine triggers the beginning of the game. Just behind the coin slot is a coin validator that measures the size, shape, weight and magnetic property of the inserted coin.

3 PLUNGER
When the plunger is pulled, its spring stretches. As it's released and recoils to its resting position, the ball is pushed up to the top of the game cabinet.

MACHINE MECHANICS

How electronics and ball physics combine for a compelling arcade pastime

DID YOU KNOW? The pinball machine that releases the most balls is SEGA's Apollo 13 machine, releasing 13 balls at once

LUCK AND SKILL

One of the core components of pinball is the flippers, but these weren't always built into the game. The original game just had the plunger and was purely a game of luck – with the odd bit of cheating as players lifted and tilted the machines to benefit their score. The obstacles inside the machine and the angle and force at which the balls entered determined the final score. This made pinball gambling rather than a game of tactics and timing, leading to the machines being banned in many cities.

In 1947, flippers were incorporated into the machines, revolutionising the game. Although pinball still relies on some luck, players have mastered ball manipulation when faced with different scenarios. Experienced players learn the angles the flippers need to be at and the necessary force to apply to hit and guide the ball to the top-scoring areas of the machine.

Pinball flippers are usually positioned at the bottom of the machine, just above the drain

6 PROTECTIVE GLASS
The cabinet that the machine is encased in is made of clear glass. While the game takes place inside the machine, all of the controls are located outside the box.

2 FLIPPER CONTROL
Each flipper is connected to an iron rod. When the button at the side of the machine is pressed, electricity flows through a coil of wire next to the rod. This creates an electromagnet that attracts the flipper's rod and moves the flipper.

1 POP BUMPER
As the ball rolls onto this skirting underneath the bumper, it triggers an electronic signal. This causes the bumper to clamp down and push the ball away from the bumper quickly.

Did you know?
Pinball originated from European lawn games

5 FACTS PINBALL HISTORY

1 PINBALL RAIDS
Pinball was banned in New York in 1942, and the police carried out raids to find the illegal machines.

2 BESTSELLER
The Addams Family-themed pinball machine released in 1992 is the best selling pinball game of all time.

3 FIRST TALKER
The first talking pinball machine, called Gorgar, was invented in 1979. It could say seven words: Gorgar, speaks, beat, you, me, hurt and got.

4 MULTIPLAYER
The Duette pinball machine, launched in 1955, was the first to allow two players to battle each other at the same time.

5 TILT TECHNIQUE
In 1934, pinball designer Harry Williams added a tilt mechanism to be used when the ball got stuck in the corner of the machine, which prevented further play.

© Alamy / Getty / Illustration by Adrian Mann

EYE TRACKING EXPLAINED

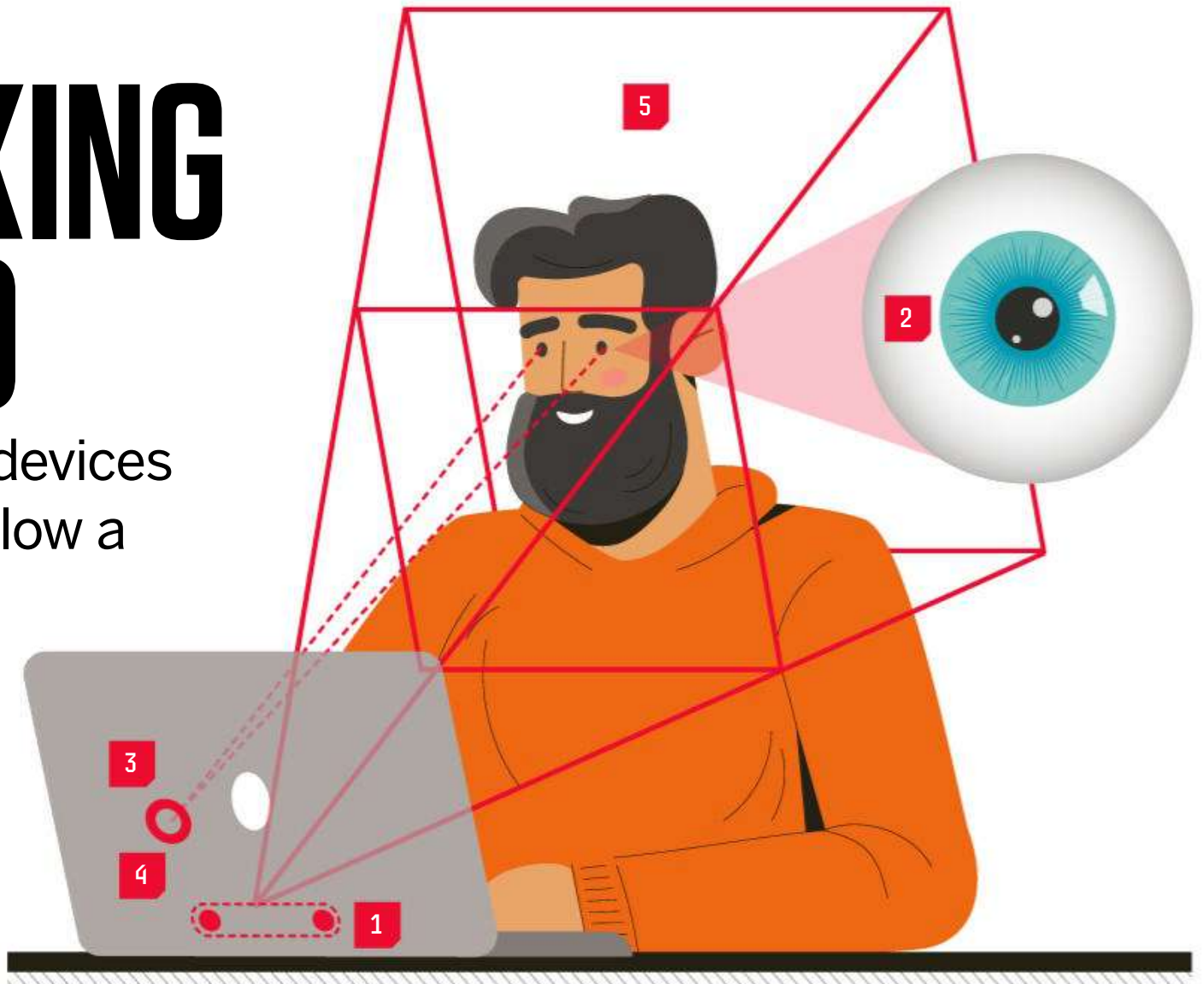
How and why electronic devices employ technology to follow a user's line of sight

WORDS **SCOTT DUTFIELD**

Eye tracking is a combination of sensory hardware and analytical software that pinpoints and tracks the movement of a person's eyes. This has been around since the early 1900s, when psychologist Edmund Burke Huey created a contact lens with a needle attached to help assess the fluency of a person's reading ability. Since then, the modern era of eye tracking technology has digitally evolved beyond the need for uncomfortable contacts.

To track the movements of each eye, the system uses a combination of cameras and infrared light. Infrared light is fired at the eye, which is reflected by the eye's cornea and received by the system's camera. Analytical software then records changes in the orientation of the reflected light, ultimately building a pattern of movement and tracking the eye. This type of tracking has been used in several different industries. Marketing researchers use it to analyse how people respond and engage visually with products and their packaging. Game developers such as Sony incorporate eye tracking technology into virtual reality games. Ditching the traditional controller, Playstation's *Before Your Eyes* lets players navigate through the game's story by simply watching and winking. Eye tracking has also been incorporated into other technologies, such as Acer's 3D laptops and SpatialLabs tablets.

3D artists can a ConceptD 7 SpatialLabs Edition 3D laptop to bring their work to life with eye tracking



TECHNOLOGICAL VISION

How eye tracking keeps tabs on your pupils

1 CAMERA
Eye-tracking cameras are equipped with near-infrared sources and light-sensing cameras.

2 SEEING THE EYE
When infrared light comes in contact with the eye, it passes through the pupil and is reflected by the cornea.

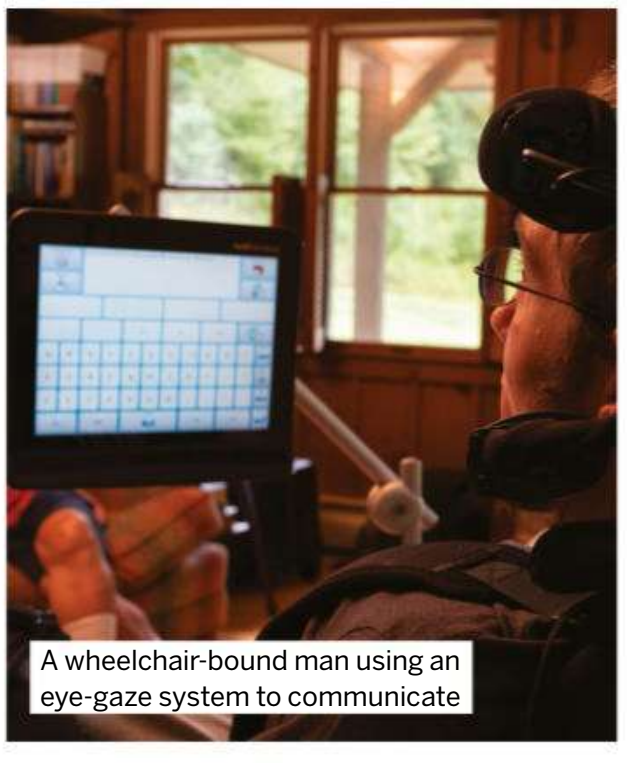
3 FINDING A PATTERN
Data from the reflected infrared light creates a referable pattern of eye movement.

4 RECOGNITION
Machine-learning software processes the reference pattern of the eye and records where the pattern moves.

5 LIGHT FIELD
Infrared light is emitted to create a field of light which reveals two points of reflection from the eye.

TALKING WITH YOUR EYES

One of the most revolutionary ways that eye-tracking technology has changed the world is to assist people who have disabilities. It can give a voice to those who suffer from conditions that impede a person's ability to speak, such as multiple sclerosis (MS) or cerebral palsy. Often referred to as gaze systems, these devices allow people to use their eyes to carry out a whole host of tasks, such as emulating a mouse for internet browsing and remotely operating televisions. This technology has also enabled people to communicate with others by typing out words with their eyes or selecting pre-saved phrases.



A wheelchair-bound man using an eye-gaze system to communicate

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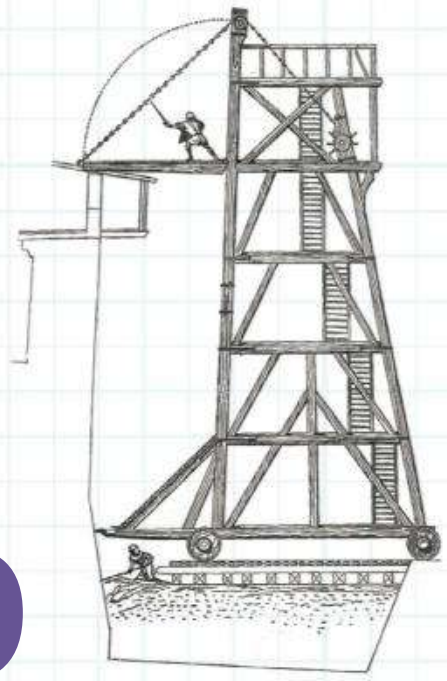
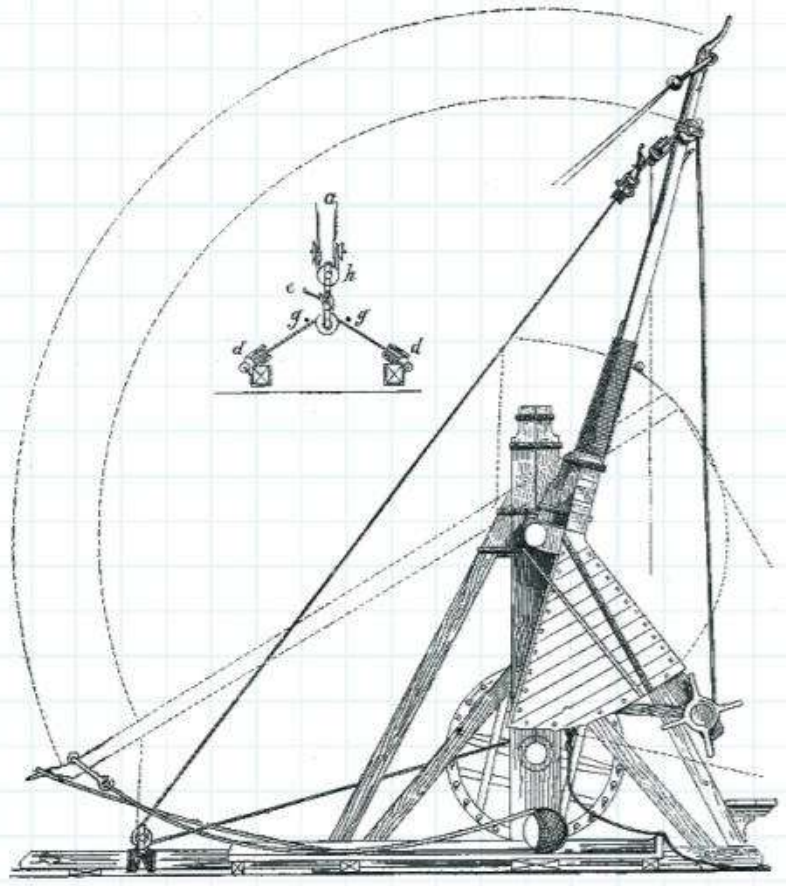
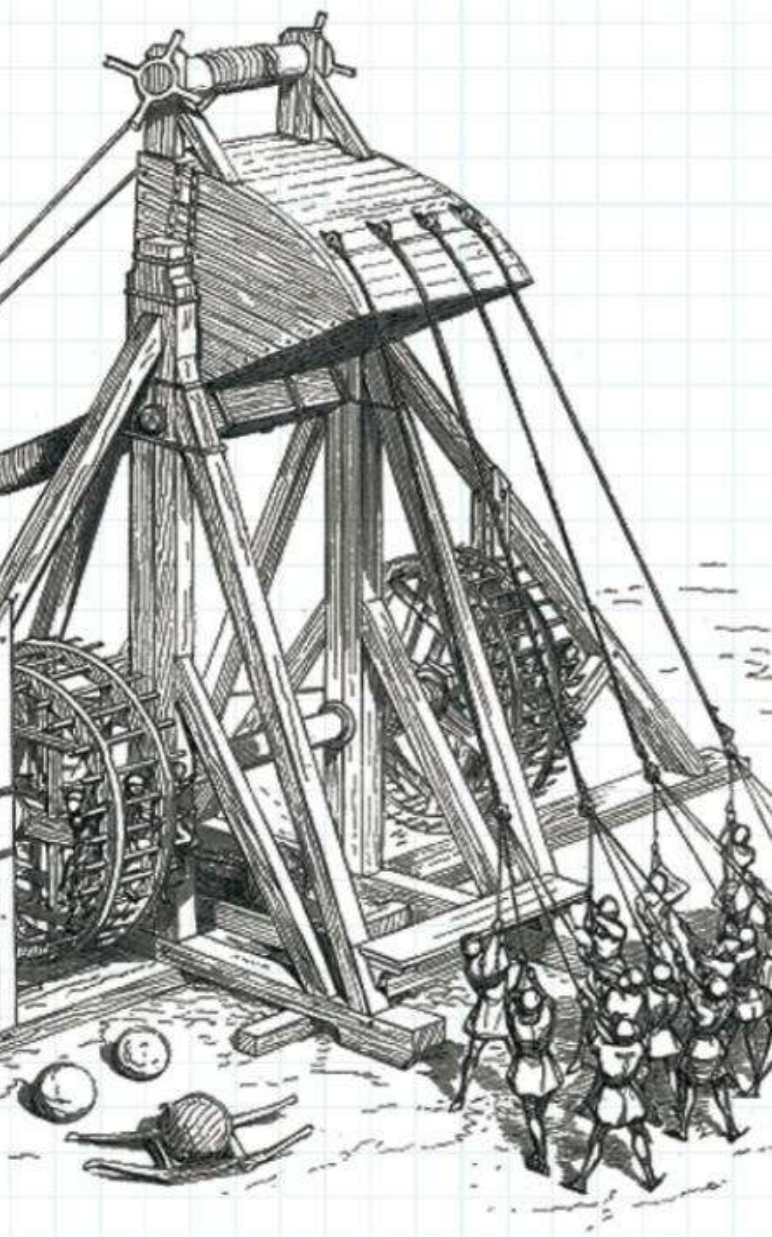




How to capture a MEDIEVAL CASTLE



WORDS **JACK GRIFFITHS**

From demolishing walls to starving out defenders, a siege in the Middle Ages required innovative tactics, stamina and determination

DID YOU KNOW? The Citadel of Aleppo in Syria is considered the oldest castle in the world

At the unsuccessful siege of Dover Castle in 1216, the castle's outer defences kept intruders at bay

Castles were the power bases of the Medieval world. Occupied by kings, nobles and knights, defeating one of these strongholds wasn't easy. To successfully bring one down, a solid strategy was a must. First, the attacking force would need to occupy the surrounding lands to instil fear in the castle owners. If negotiation and diplomacy failed, an attacking force could resort to intimidation by seizing all supply lines and pillaging the locality.

If a white flag was still not forthcoming, the siege would officially begin. Prior to an attack, a messenger would sometimes be sent to the besieged castle, informing defenders of the force's intentions. After this notice was heeded, the castle would be restocked of weapons and provisions, ready to weather the coming storm.

There were many ways to try and break down the fortifications. An expensive yet destructive method was the use of huge wooden siege engines. Ranging from long-range trebuchets to metal-capped battering rams, a castle could be assaulted from all directions. The best carpenters, blacksmiths and engineers were drawn from around the land to create the machines of war, while knights who owed service provided the military muscle. Livestock, timber, tools and provisions would also be acquired. A camp was set up a safe distance from the castle and preparations would begin.

Meanwhile, the defenders made preparations of their own. Usually, a scorched-earth policy was implemented. This would devoid the surrounding area of any arable land to plunder, significantly depleting an advancing army's available resources. This involved doing major damage to the defenders' own land, but it was worthwhile if it helped prevent a siege. Inside the castle, men would be armed and stores restocked in anticipation of what was to follow. Sieging a castle was an imposing and frightening prospect and required inventive strategies, plentiful resources, a steely determination and a slice of luck for good measure.

Did you know?

Castle comes from the Latin word for 'fortress'

5 BLOODY MEDIEVAL SIEGES

1 JERUSALEM 1099

Jerusalem is one of the most sieged cities in history, and in 1099 it experienced one of the bloodiest. Part of the First Crusade, the Muslim and Jewish population was massacred as the Crusaders burst through the gates, suffering heavy losses themselves.

2 ACRE 1189 TO 1191

After negotiations failed, Saladin besieged the Crusader stronghold of Acre during the Third Crusade. The siege lasted a total of 23 months and resulted in many Crusader deaths, but Saladin was defeated and dealt a serious blow in his attempt to retake the Crusader kingdom.

3 CHÂTEAU GAILLARD 1204

The impressive defences of this French castle were eventually brought down by King Phillip after eight months of battle. The siege included almost every type of siege engine and was fought on land and sea.

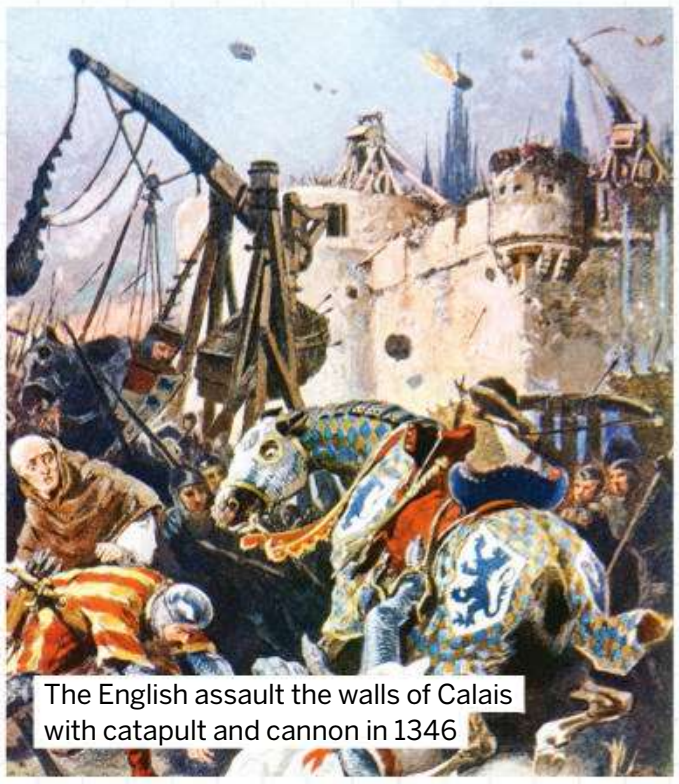
4 ROCHESTER 1215

Part of the First Barons' War, the siege of Rochester was an example of attackers digging under a castle. A fire fuelled by pig fat was started underneath the battlements, and the defenders eventually surrendered as winter set in.

5 CAHIR 1599

The most impregnable castle in the whole of Ireland, the Earl of Essex laid siege to the fortress under the orders of Queen Elizabeth I. It quickly succumbed to artillery, demonstrating how the advent of the cannon helped end the age of the Medieval castle.

© Mary Evans



The English assault the walls of Calais with catapult and cannon in 1346

CHOOSE YOUR WEAPONS

With money to burn and a realm to conquer, barons would splash out on the biggest and best siege engines available

For the best possible chance of victory during a siege in the Middle Ages, huge siege engines were financed to bring death and destruction upon a fortress and its inhabitants. These imposing machines rumbling into view could even frighten castles into submission before an arrow was fired. Different siege engines were useful against different types of castles, so commanders would purchase what they needed depending on the terrain and defences they were going to face. As castles were often built with sieges in mind, many were surrounded by moats and steep climbs. It was also important to take a range of siege engines to keep the attack varied and relentless. For example, siege towers could soak up arrows and keep defenders at bay, while trebuchets and battering rams did damage to other parts of the stronghold. To ensure their machines would last and be as effective as possible, barons would source the best builders and tools to create their wooden army.

Did you know?

Archers and crossbowmen would ride atop siege towers

SIEGE TOWER

These towering structures were deadly in the Medieval era

1 THREE STOREYS HIGH
The largest of the towers would have three levels of attack. While the top section peered over the walls, the middle housed more troops who could fire out at will and also had a ladder to reinforce the top level.

2 DRAWBRIDGE
Protecting the soldiers until they were right at the gates, the drawbridge would be flung upon and the infantry would pour out. One snag was the narrowness of the drawbridge, which would often only let soldiers out in single file.

3 BATTERING RAM
As well as being effective weapons on their own, battering rams could be housed within a siege tower. Now covered and part of a larger mechanism, the ram would bring down gates and walls while troops attacked the top of the battlements.

4 DIMENSIONS
At eight metres high, siege towers were tall enough to rise over most castle defences. In response, many fortifications dredged moats or were constructed on the top of a hill to nullify their effectiveness.

DID YOU KNOW? The trebuchet was invented by Mariano Taccola around 1400 CE

TREBUCHET

Prior to the age of the cannon, these were the most forbidding siege engines of the Medieval era

6 DIVERSION TACTIC
The relentless barrage from a team of trebuchets could keep castle defenders constantly pinned down. This enabled other siege engines and methods of attack to be more effective while the defenders dealt with the trebuchet threat.

5 AMMUNITION
Using the counterweight to great effect, huge 90-kilogram rocks battered down stone walls and knocked defenders off battlements. Diseased animals and even dead human bodies were also chucked into the castle courtyard in an attempt to infect inhabitants.

7 DIMENSIONS
At up to 18 metres long, the trebuchet was a monster of Medieval siege warfare. With a range of about 200 metres, it could be constructed far out of range of fortifications.

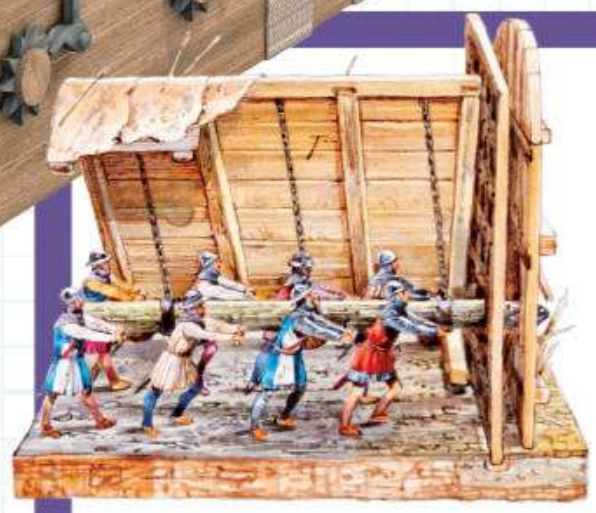
8 FIRING SYSTEM
The huge arm gave the trebuchet an excellent range in which to launch its projectiles. On average the beam would be about 8 to 12 metres long, and the arm turned on an axle that was joined to the machine's structure.

9 COUNTERWEIGHT
The use of a weighted system rather than torsion gave the trebuchet an advantage over a mangonel. By using weights, it could launch larger loads at a quicker rate.

10 DRAWING THE DEFENDERS OUT
As it was often out of range of a castle's archers, trebuchets could entice the defenders into raising the portcullis and coming out to battle, away from the safety of the battlements.

11 TRIGGERS AND LEVERS
The efficiency and reliability of a trebuchet was demonstrated by its trigger. When the system was activated, it let go of the counterweight, launching the arm into attack mode.

12 STAKES
Despite its imposing figure, a trebuchet could be quite brittle. Stakes were hammered into the ground to prevent it falling or lifting when fired. It would have to be well protected, as one direct hit could break the whole mechanism.



BATTERING RAMS AND CATAPULTS

Better known as a mangonel, the catapult was an update of the Roman onager, which used torsion to fling projectiles. Perhaps the most primitive of all siege weapons, the battering ram was also very effective. Used to pound down walls, the wooden stake was often steel capped and could be part of a larger mechanism.

© Alamy / Getty / Sol90

LAUNCH THE ATTACK

When negotiations failed and intimidation proved futile, siege was the only option

Getting a siege underway wasn't just a matter of loading up the engines and firing the first projectile. Depending on the forces available and the layout of the castle, each attack would begin differently. Most of the time, though, attackers would first attempt psychological warfare by launching severed heads into the castle. Then, the first target would be a weak point of the wall. In response, defenders barricaded their weakest points and increased attacks on the most potent siege engines. The key to a successful siege was continuous attack, as a break in hostilities would give defenders time to repair damage. Also essential was stopping supplies reaching the castle, preventing the arrival of weapons and resources. If the breakthrough still didn't come, aggressors would spread out their attacks. Castles were often undermanned, so attacking from all angles could overwhelm them. If this still didn't work, it was time to get creative. Mining was a common way of getting into a castle while staying out of the line of fire. Sieges could take months or even years, but attackers could often wait it out for longer than defenders. If the castle supply lines were cut off, it was only a matter of time before malnutrition and then starvation set in.

Did you know?

Windsor Castle is the oldest inhabited castle

1 REINFORCEMENTS

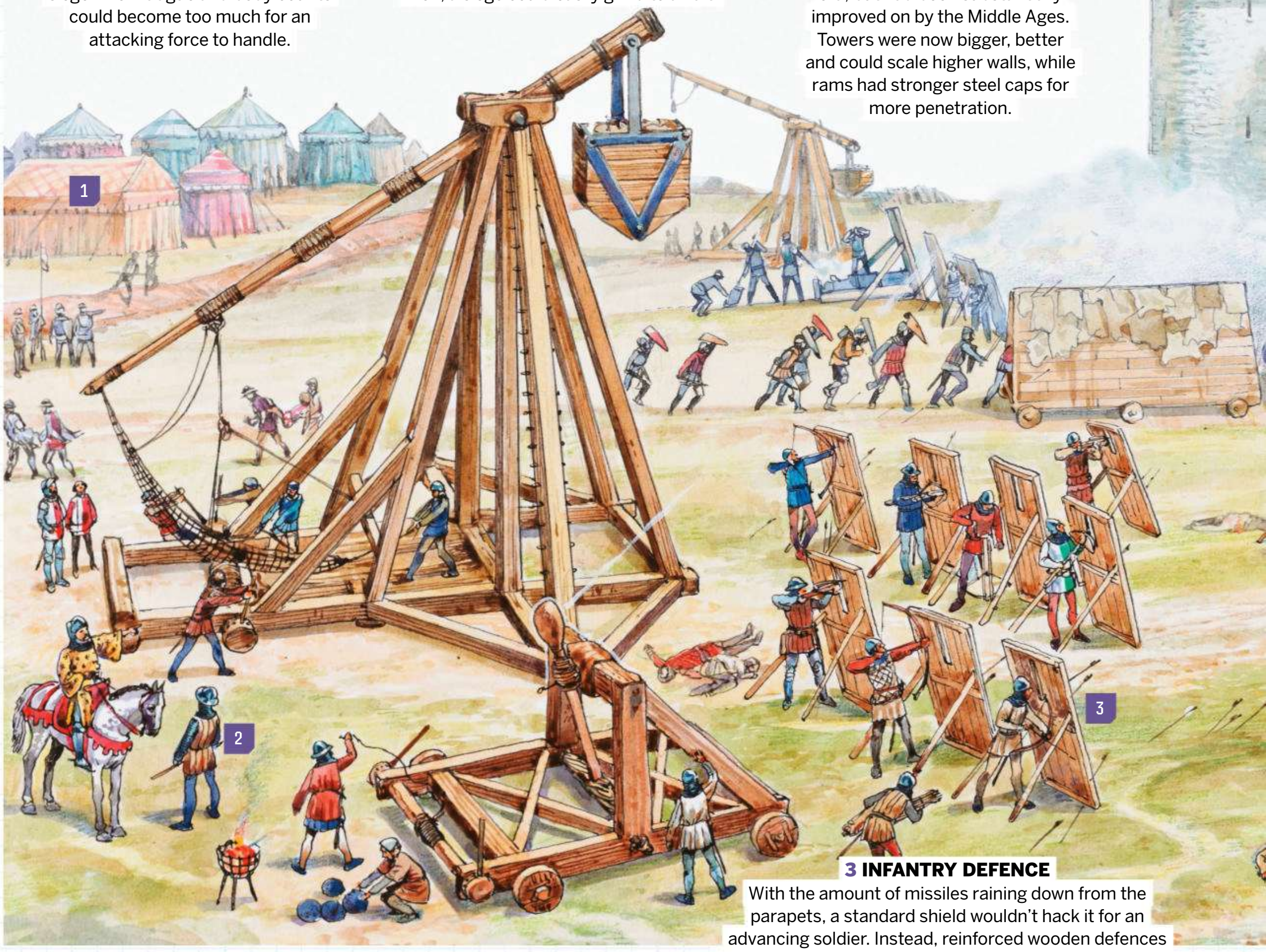
A long siege required more than the initial raiding party. Reinforcements were a necessity for a long, drawn-out siege when fatigue and body counts could become too much for an attacking force to handle.

2 UNSUNG HEROES

Sieges were just as much about constructors as they were soldiers. Siege engines would often need repairing or rebuilding, and without these men, a siege could easily grind to a halt.

4 WHAT HAVE THE ROMANS EVER DONE FOR US?

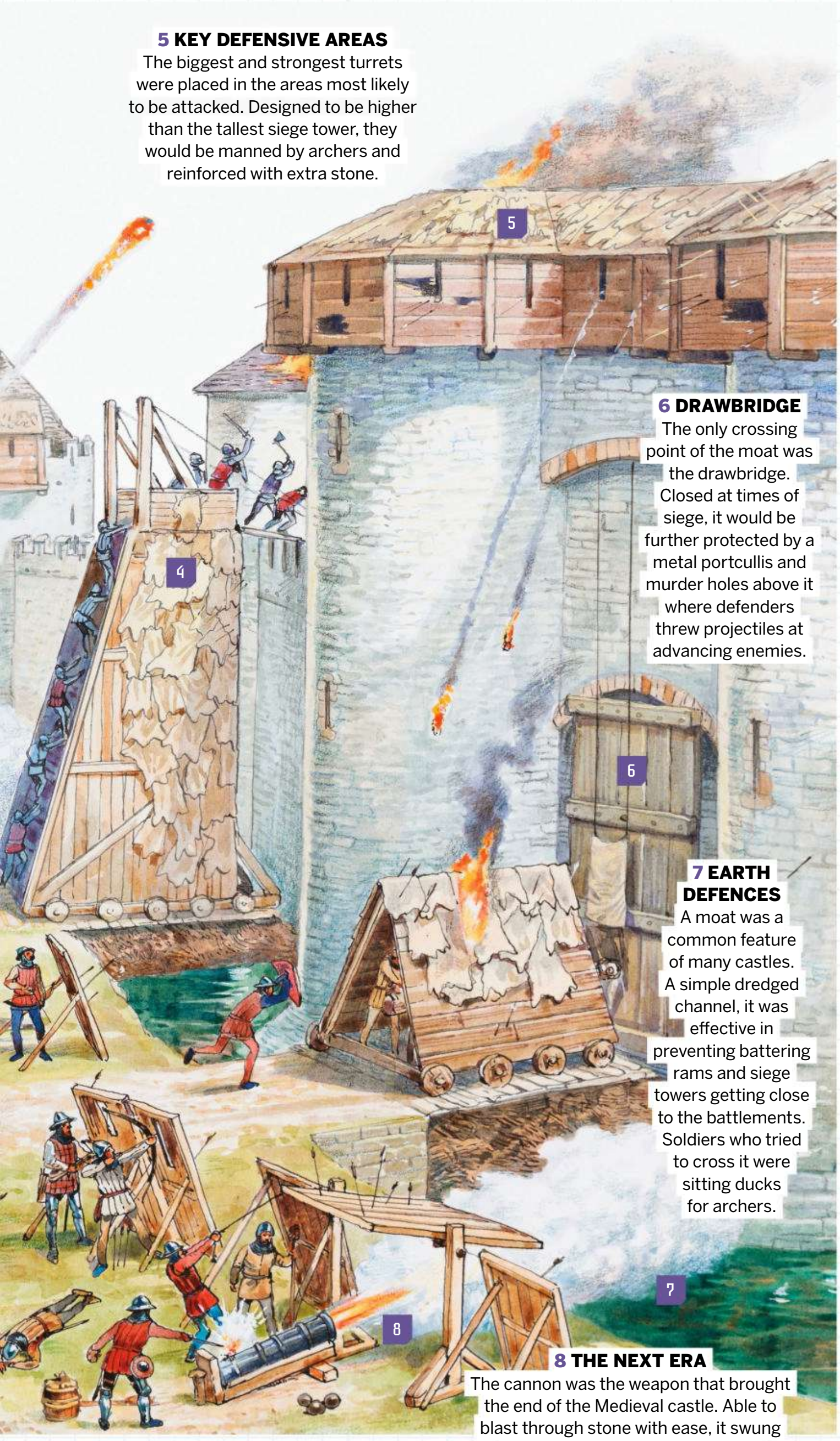
Both battering rams and siege towers were first used in the ancient era, but had been substantially improved on by the Middle Ages. Towers were now bigger, better and could scale higher walls, while rams had stronger steel caps for more penetration.



3 INFANTRY DEFENCE

With the amount of missiles raining down from the parapets, a standard shield wouldn't hack it for an advancing soldier. Instead, reinforced wooden defences would be set up to protect the whole body from projectiles.

DID YOU KNOW? Cinderella's Castle at Disneyland is based on Neuschwanstein Castle in Germany



5 KEY DEFENSIVE AREAS
The biggest and strongest turrets were placed in the areas most likely to be attacked. Designed to be higher than the tallest siege tower, they would be manned by archers and reinforced with extra stone.

6 DRAWBRIDGE
The only crossing point of the moat was the drawbridge. Closed at times of siege, it would be further protected by a metal portcullis and murder holes above it where defenders threw projectiles at advancing enemies.

7 EARTH DEFENCES
A moat was a common feature of many castles. A simple dredged channel, it was effective in preventing battering rams and siege towers getting close to the battlements. Soldiers who tried to cross it were sitting ducks for archers.

8 THE NEXT ERA
The cannon was the weapon that brought the end of the Medieval castle. Able to blast through stone with ease, it swung sieges in favour of the attackers.

HOW TO DEFEND A CASTLE

When the attackers were on your doorstep, these measures could get you out of trouble

LOOK FOR SPIES
Prior to a siege, spies were often sent out to report on a castle's frailties. To prevent a Trojan horse-like attack, castle rulers would keep close tabs on who and what was entering and leaving their gates.

RIPPLES IN THE WATER
Underground, some of the most vicious fighting of the entire siege was fought in tunnels. If the defenders lost here, their perimeter would be compromised, so guards would place a pot of water near the walls that rippled when miners were below.

SPECIALISED BATTLEMENTS
Castle walls, built with attack in mind, were littered with anti-siege measures. Arrow loops gave archers a good shot at attackers, while towers and gatehouses were constructed as troop garrisons. A barbican passage at the entrance would act as a death trap to oncoming foes.

RETREAT TO THE KEEP
When the outer walls were breached, a strong keep was essential. The centrepiece of a castle, if the keep was surrounded, the only chance would be to hold on until help arrived and hope the food didn't run out.

ALLIED ASSISTANCE
If an assaulting force was preoccupied with a siege, it would be vulnerable to an attack from the rear. Any distraction would relieve the pressure and allow a counter-attack to vanquish the enemy once and for all.

© Getty

WHAT TO DO WITH THE ENEMY

After defeat, what was left of the defenders had to be dealt with

TAKE PRISONERS

The defenders would eject women and children out of the keep. This cruel tactic gave the attackers prisoners to be used as a bargaining tool for surrender, but now only the best fighters remained, and with a much larger food supply.

TOTAL ANNIHILATION

A popular method of ending a siege was killing all those that stood in the way. Sometimes the nobility were held for ransom, but at others, like the siege of Bedford Castle in 1224, everyone could be killed as a warning to others.

NEW TENANTS

If the castle was in a strategic location or was an influential power base, the invading army would take it for their own. It would act as an outpost on the frontier of a land and the former defenders would be exiled or enslaved.

IT'S A TRAP

Defenders of a castle would implement all types of booby traps. These would be left for the new occupants to find for themselves, and sometimes it was done the hard way. Using a captured prisoner would be a good tactic.

RAZE TO THE GROUND

The advent of the cannon made castles much easier to demolish. For many castles, the English Civil War was the last hurrah, but they still proved valuable, such as when Stirling Castle held out against the Jacobites a century later.

Catapults and trebuchets were devastatingly effective at bringing down castle walls

DID YOU KNOW? The first siege of Ceuta lasted for 26 years – the longest in history

TAKE THE CASTLE

With the outer walls down, it was time to storm the courtyards and break into the keep

When the walls were overrun and bodies lay strewn around the bailey, the keep – the centrepiece of the castle defences – was the only thing that stood in the way of victory. Some keeps were merely the central building, but many had defences of their own. They could contain arrow loops and crenellations to help with the last-ditch defence of the castle. As the attacking soldiers gathered in the bailey, they would be vulnerable to arrow fire. Only heavy plate armour stood any chance against the power of a crossbow bolt, so soldiers with chain mail would be in danger from archers until the keep was breached. The keep would also contain the castle's stores, so in the event of a siege, the population were best placed to try to hold out for as long as possible.

Did you know?

Edinburgh Castle has been besieged at least 23 times

With the keep the only structure now occupied by the defenders, the attackers could benefit from controlling the other buildings in the castle. The armoury could be pillaged for extra weapons and tools, and after the siege ended, stores could be raided and horses taken from stables to bolster the army for the next assault. The defence of the keep was always a last resort, and usually meant victory for the aggressors. Once the castle was taken, it was up to the attackers to decide the fate of the castle ruler – this depended on how merciless they were. When the enemies had all been dealt with, there was a choice to be made: rule the castle and make it the centre of a new occupied kingdom or raze it to the ground and let the ruin stand as an example of what happens when a castle puts up resistance.

The siege of the castle of Torres Novas, Portugal, by Islamic forces

© Look and Learn / Mary Evans

DID YOU KNOW? Coins were made with ridged edges to show when silver or gold was clipped from them

WHO INVENTED MONEY?

From the first coins to cashless transactions, discover how money has shaped our world

WORDS **AILSA HARVEY**

It isn't the only indicator of success or happiness, but there's no denying the importance of money in today's world. Money was invented for the same purpose that it serves today: to allow people to trade items with others in a relatively fair manner. Money is earned through labour or by selling goods and is used to purchase everything we need to live, from clothing and shelter to food.

In today's technological age, people assess their financial stability by reading a number on a screen. But before money could be distributed virtually, each coin was made from a precious metal or other valuable item. Today this aspect remains fundamental. All of the money in the world has to remain at a stable value, otherwise currencies would lose their power.

Did you know?

There are more than 1.5 million contactless ATMs in the world

Although the form money has taken has changed over millennia, the purpose has remained consistent across the globe. Here we take a look at the history of money – including some of the most ancient forms of payment – and explore how different cultures developed similar systems for trading essential and luxury goods.

THE WORLD'S FIRST COINS

Between 1200 and 546 BCE, the Lydian Empire ruled in western Asia. During the reign of King Alyattes, between 635 and 585 BCE, many historians believe the empire began to use the world's first coins, called the Lydian stater. Despite being invented by Lydians, these coins may not have been used to buy items within the kingdom itself. Because of the lack of staters found in the ruins of shops and marketplaces, archaeologists believe the coins were for trading far outside the Lydian community.

1 ELECTRUM
The Lydian stater was made of a gold-silver alloy called electrum. Each coin had a consistent mix of around 55 per cent gold, 45 per cent silver and a small amount of copper.

2 LION
The Lydian lion design showed that the coin was official money of the Lydian king.

3 BULL
Together with the lion, the two animals on the face of this coin represented the empire's strength.

4 IRREGULAR SHAPE
Despite being irregular in shape, the coins were made to be roughly equal in weight. They each weighed the same as around 220 grains of wheat.

THE BARTER SYSTEM

Today we use money to obtain any items we might want or need. But before the invention of money, how did people get hold of the resources they needed to survive? The answer is bartering. The barter system involved swapping items of an agreed equal value. Because each item may be considered more or less valuable between individuals, this process involved negotiation – for example, how many vegetables is a cow worth?

Bartering can be traced back to 6000 BCE, when Mesopotamian tribes would swap items such as weapons, food, tea and spices. However, there were some difficulties in the system, as it required specific circumstances. When a family sought a particular item, they needed to know someone who owned spares. As well as this, they needed to own an equally valuable item themselves that they could offer in exchange. Securing a good deal this way could take considerable time.

This ancient Egyptian illustration depicts the bartering market of the 15th Dynasty, which ruled from 1650 to 1550 BCE

© Alamy / Getty

5 COIN ALTERNATIVES

1 CATTLE
9000 TO 6000 BCE
Livestock such as cows, camels and sheep were valuable as sources of meat, milk and leather. They were used as early methods of pricing products. For example, one cow might have equaled two goats.

2 COWRIE SHELLS
1200 BCE
Cowrie shells, which are found at the shores of the Pacific and Indian oceans, were nearly as widely used in ancient times as coins are today. They're small, portable and valued highly by many African cultures. However, this currency could only be used where the shells weren't so naturally abundant.

3 LEATHER MONEY
118 BCE
30 by 30 centimetre squares cut from deerskin were used in China. These early banknotes were white with bright borders.

4 PAPER
806 CE
Paper money followed coins as a lighter material to transport when collected in large bundles. The first paper coin replacements were made in China.

5 WAMPUM
1535 CE
Strings of beads made from clam shells were used as currency among Native American tribes. Strings of 8, 24, 96 and 480 beads were equal to 1, 3 and 12 pence and five shillings.

PAPER CASH ORIGINS

It was during the Tang dynasty in China that paper money was first used by merchants. The reason that this form of money was used was due to the problems faced by rich merchants. When they received large sums of money, the accumulating metal would weigh down their vessels. This would force them to leave some of the money behind with someone who was trustworthy, in exchange for a piece of paper that detailed how many coins had been deposited there. These notes were used in China for 500 years before people in Europe adopted this method. When this became a common payment method, the paper replacements became as accepted a form of payment as the coins themselves.

Early Chinese paper notes were discontinued because their production wasn't regulated well, leading to inflation

THEORY OF CREDIT

When someone pays with a credit card, they can use borrowed money to pay for items. Without handing over any money at the time of spending, someone paying with credit can make a purchase by presenting a record that they will pay the bank their debt at a later date. The earliest record of credit comes from Henry Dunning Macleod, a Scottish economist who explained in 1889 how credit could be used at the same value of physical money. Macleod stated that "money and credit are essentially of the same nature: money being only the highest and most general form of credit".

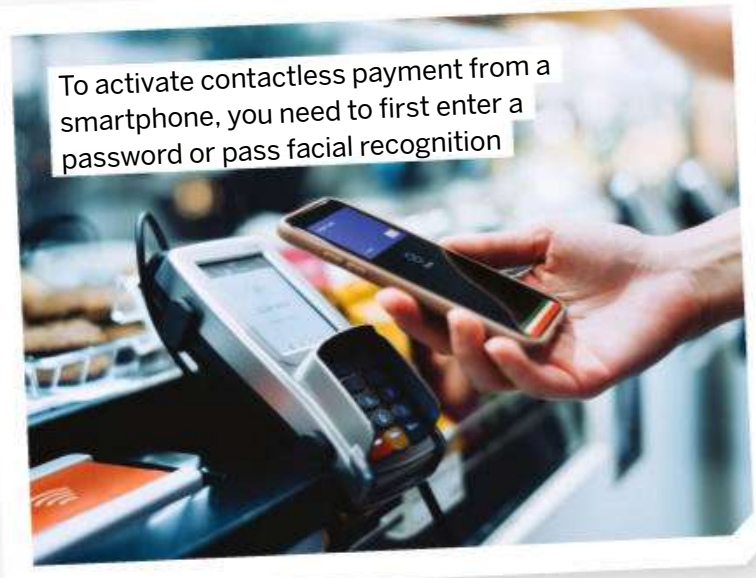
A credit card allows the owner to borrow a certain amount of money

MODERN MONEY

The way we pay today was shaped by traders over centuries as they lugged large quantities of heavy precious metals. So how is it that today we can spend large sums without a single coin or banknote in our pockets? The future of money is electronic, and the shift has already begun. Three-quarters of the world's adults already have a digital account from which they make online payments. When a bank card is inserted into a card machine, the price of a purchase is recorded online. This serves as a virtual transfer of money between two bank account owners instead of having to hand over the physical money. One of the main benefits of this is the ability to pay someone for an item or service from overseas without needing to make the journey across the globe.

With more personal electronic devices being connected to the internet, today you can transfer money to someone using your smartphone or even your watch. This process utilises a technology called near-field communication (NFC). As long as your watch or phone has been connected to your bank account, you can hold the device close to a card machine and the two devices will transfer data regarding the money being paid and received between the two.

Did you know?
Coins can stay in circulation for around 30 years



To activate contactless payment from a smartphone, you need to first enter a password or pass facial recognition

DID YOU KNOW? Since 1866, no living person has been incorporated into the design of US currency

THE EVOLUTION OF COINS

Explore the world's metal money that's dictated wealth over several centuries

1413 TO 1422 CE
HENRY V COINS
King Henry V was the king of England for less than ten years, meaning the number of coins made during his reign was limited.

995 TO 1100 CE
SCANDINAVIAN
Most Viking money was made of silver. By raiding other ships, the Vikings used coins before they made their own. By the end of the 10th century there were Scandinavian coins. These were made with the aim to pay off invaders.

912 TO 913 CE
BYZANTINE GOLD
These coins were used for trade during the Eastern Roman Empire. They were made of pure gold and were slightly inverted, which may have assisted in their stacking.

1794 TO 1795 CE
THE FIRST DOLLAR
The first American dollar coin was called the Flowing Hair dollar. It was based on the Spanish dollar, and so matched its size and weight. The design featured Lady Liberty with her hair flowing behind her.

375 TO 414 CE
CHANDRAGUPTA GOLD DINAR
These ancient Indian coins were designed with a figure of the king Chandragupta with a halo around his head.

600 BCE
CREATING COINS
Coins have existed for over 2,700 years. The oldest coin in the world, a Lydian coin, is kept in the British museum.

29 TO 36 CE
PILATE PRUTAH
Minted by Roman governor Pontius Pilate, these coins are valuable in Jewish and Christian communities as their circulation coincides with when Jesus lived.

118 BCE
HAN DYNASTY BRONZE
The Wu Zhu coins of China were made of bronze and had a gap at the centre to make them easy to carry in collections on ropes.

59 TO 27 BCE
ROMAN IMPERATORIAL
These silver coins were minted just before the assassination of Julius Caesar. They had the face of Caesar on one side, with the words 'Dictator in Perpetuity'.

© Alamy / Getty / Wikimedia Commons; John E. Sandrock

STEPHEN HAWKING

The theoretical physicist who changed the way we see the universe

WORDS **SCOTT DUTFIELD**

Hawking was born on 8 January 1942 in Oxford to medical researcher Frank Hawking and Isobel Eileen Hawking. During his early education at St Albans School in Hertfordshire, Hawking's interest in science and contemplation of the universe began. With a nudge from his biologically minded father, Hawking enrolled in natural science at University College, Oxford, in which he obtained first-class honours. It was during this time that Hawking was diagnosed with a motor neuron disease called amyotrophic lateral sclerosis (ALS), otherwise known as Lou Gehrig's disease. At almost 21 years old, doctors told Hawking that he likely wouldn't survive for more than two years with the disease. Nevertheless, Hawking continued in his academic pursuits, receiving his doctorate in cosmology from Trinity Hall, Cambridge, for his thesis, entitled *Properties of Expanding Universes*, in 1966. Within the same year, Hawking received a fellowship to Gonville and Caius College, where he ultimately spent the rest of his career uncovering the mechanics of the universe.

Hawking's early research sought to understand the laws that govern the way the universe works, how it began and how it might end. In 1970, Hawking and fellow physicist and Oxford classmate Roger Penrose published a joint paper: *The singularities of gravitational collapse and cosmology*. In this paper, Hawking and Penrose characterised the astronomical anomalies known as black holes. It not only challenged ideas in physics, but also confirmed the concept of the Big Bang as the birth of the universe, as outlined in Albert Einstein's theory of general relativity in the 1940s. From then on, Hawking dedicated decades of his career to understanding the physics behind black holes and the interactions between them and the rest of space. He also proposed that the universe is boundaryless, allowing you to infinitely travel around or through the universe and never encounter a wall.

In the last three decades of Hawking's life, he not only continued to publish academic literature, but also published several popular science books to share his knowledge with a wider audience. His most popular book, *A Brief History of Time*, has sold almost 10 million

Above: Hawking with his daughter Lucy Hawking in 2007

Right: Hawking appearing at Princeton University on 10 October 1979

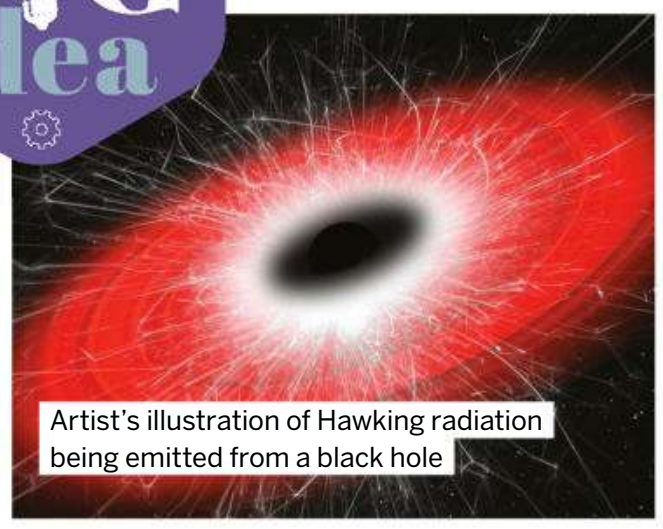
Right inset: Hawking and Eddie Redmayne, star of biopic film *The Theory of Everything*, at its London premiere

Did you know?

Hawking gained 13 honorary degrees during his lifetime

The BIG idea

HAWKING RADIATION



Artist's illustration of Hawking radiation being emitted from a black hole

Hawking will be remembered for making a myriad of revelations about the universe. But one such groundbreaking discovery involved redefining the physics of black holes. In 1974 Hawking published a paper called *Black hole explosions?* in which he outlined a new singularity theorem that united Einstein's theory of general relativity, which outlines the physics of space-time, with quantum theory, which explains the behaviour of matter and energy on an atomic level. He theorised that matter not only fell into black holes, but that particles are also emitted from them. This is now a widely accepted phenomenon aptly named Hawking radiation.

5 THINGS TO KNOW ABOUT STEPHEN HAWKING

1 ANTIGRAVITY
In 2007 the then-65-year-old physicist boarded a modified Boeing 727 aeroplane, where he experienced zero gravity during flight.

2 CHILDREN'S BOOK AUTHOR
Along with his daughter Lucy Hawking, the pair wrote a series of children's books called *George and the Big Bang*, in which George uses a secret power to travel through space.

3 BETTING MAN
During his lifetime, Hawking made several lightweight bets about serious science, many of which he came to regret, including that Cygnus X-1 wasn't a black hole, which he later conceded.

4 HE JOINED THE ROWING TEAM
To meet friends during his time at Oxford, Hawking joined the university's rowing club as the team's coxswain, who steers and directs the other rowers.

5 PNEUMONIA
While on a trip to Geneva in 1985, Hawking became ill with pneumonia, which almost claimed his life. He became so unwell that doctors performed a tracheotomy to help him breathe.

DID YOU KNOW? Hawking was born exactly 300 years after the death of Italian physicist and astronomer Galileo Galilei

copies and has been translated into 40 different languages. "All of my life, I have been fascinated by the big questions that face us and have tried to find scientific answers to them. If, like me, you have looked at the stars and tried to make sense of what you see, you too have started to wonder what makes the universe exist," said Hawking in the 1997 PBS miniseries *Stephen Hawking's Universe*. Sadly, 55 years after Hawking was told that ALS would take his life within a couple of years, Hawking passed away on 14 March 2018, aged 76, at his home in Cambridge.

A LIFE'S WORK

The astronomical achievements of one of the greatest minds in history

1959
At 17, Hawking joined University College Oxford.

1965
Hawking met his future collaborator Roger Penrose, who was delivering a talk on singularity theorems.

1966
Hawking won the Adams Prize for his theories of the universe in his essay *Singularities and the Geometry of Space-Time*.

1970
Hawking and Penrose published a paper supporting Einstein's theory of relativity, outlining that the universe began with the Big Bang.

1973
The first of Hawking's books, *The Large Scale Structure of Space-Time*, was published.

1979
Hawking became the Lucasian Professor of Mathematics at Cambridge and was awarded the Albert Einstein medal.

1982
Queen Elizabeth II awarded Hawking with a CBE for his services to science.

1988
Hawking's most popular book, *A Brief History of Time*, was published, written for readers with a limited knowledge of physics.

2002
Hawking released *On the Shoulders of Giants*, a book that compiles the work of the greatest minds in science.

2010
Along with Leonard Mlodinow, Hawking published another popular-science book called *The Grand Design*.

© Getty

CAR CRASH ANATOMY

How today's technology can predict, prevent and assist in dangerous vehicle collisions

Police attending a collision

WORDS **AILSA HARVEY**

Today's motor vehicles provide people with a greater freedom of movement, with easier access to places of work and trips further afield from home. However, with the number of cars on the roads increasing over the years, car crashes are becoming more common.

When cars carry their passengers along a road, the engine provides the vehicle with kinetic energy. This is the energy of motion. In the event of a crash, vehicles lose kinetic energy and ultimately come to a stop, but this energy doesn't vanish. Instead it's transferred to other objects, vehicles and sometimes people, causing the damage seen in road collisions. An object that has been struck by the car may absorb the kinetic energy of the moving car or return it to the vehicle.

Today's cars are designed to take the brunt of this energy, transferring it into their metal frames which are crushed and distorted, breaking their internal components. However, despite this protective technology, the driver and passengers exposed to a collision will usually absorb a small percentage of the kinetic energy. Being much more fragile than the metal machine that surrounds them, at least one of a car's occupants will suffer from an injury in 43 per cent of car crashes.

Did you know?

Air bags were invented in the 1970s

PROTECTIVE TECHNOLOGY

The life-saving armour of modern vehicles

1 SAFETY GLASS
Instead of completely shattering when the car's windshield glass breaks, the glass fragments stick to a strong layer of plastic between the car occupants and the window.

6 SEAT BELTS
During a car crash, you're more likely to survive if you aren't thrown out of the vehicle. Seat belts are essential for securing the body to the seat.

2 AIR BAGS
When a sensor behind the dashboard detects a hard front-on impact, these bags inflate rapidly with nitrogen gas to cushion the driver and passengers' bodies.

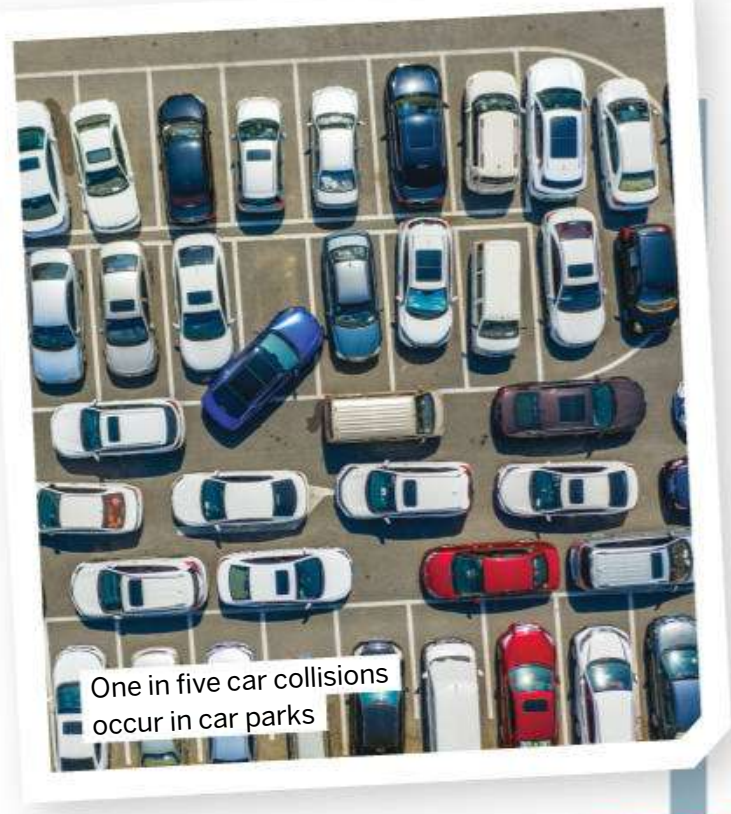
DID YOU KNOW? Most car crashes occur less than three miles from the driver's home

WHAT CAUSES A CAR TO CRASH?

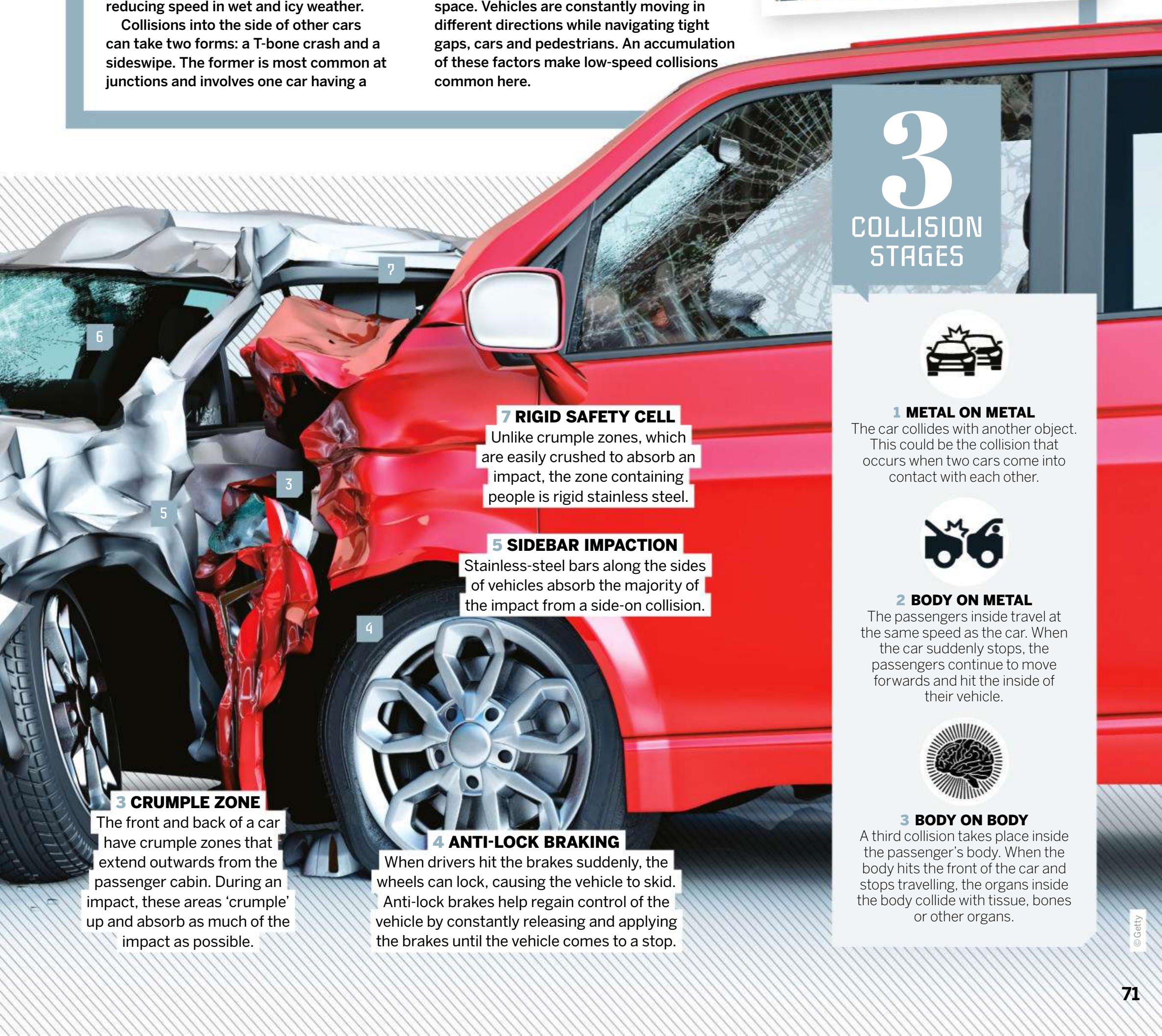
There are many ways that a car can experience a collision on the roads, each with different causes and varying levels of severity. The four most common types of car crashes are front-impact, side-impact, rear-end and car park collisions. Front-impact collisions – when two vehicles make a head-on impact with each other or a vehicle hits an object at the side of the road – are the most common form of crash. These collisions are often caused by distracted drivers or slippery roads and can be prevented by drivers keeping as focused as possible and reducing speed in wet and icy weather.

Collisions into the side of other cars can take two forms: a T-bone crash and a sideswipe. The former is most common at junctions and involves one car having a front-impact collision with the side of another. In contrast, sideswipes are lower impact and take place when two cars are parallel to each other and travel too close, making contact at their sides.

Rear-end collisions are caused by the front of one vehicle colliding into the back of another. When there's a lot of traffic this is more likely to happen, so drivers should keep their distance from other vehicles to make sure they have enough time and space to stop in an emergency. Car parks usually have a high number of vehicles in an enclosed space. Vehicles are constantly moving in different directions while navigating tight gaps, cars and pedestrians. An accumulation of these factors make low-speed collisions common here.



One in five car collisions occur in car parks



3 COLLISION STAGES

1 METAL ON METAL
The car collides with another object. This could be the collision that occurs when two cars come into contact with each other.

2 BODY ON METAL
The passengers inside travel at the same speed as the car. When the car suddenly stops, the passengers continue to move forwards and hit the inside of their vehicle.

3 BODY ON BODY
A third collision takes place inside the passenger's body. When the body hits the front of the car and stops travelling, the organs inside the body collide with tissue, bones or other organs.

7 RIGID SAFETY CELL
Unlike crumple zones, which are easily crushed to absorb an impact, the zone containing people is rigid stainless steel.

5 SIDEBAR IMPACTION
Stainless-steel bars along the sides of vehicles absorb the majority of the impact from a side-on collision.

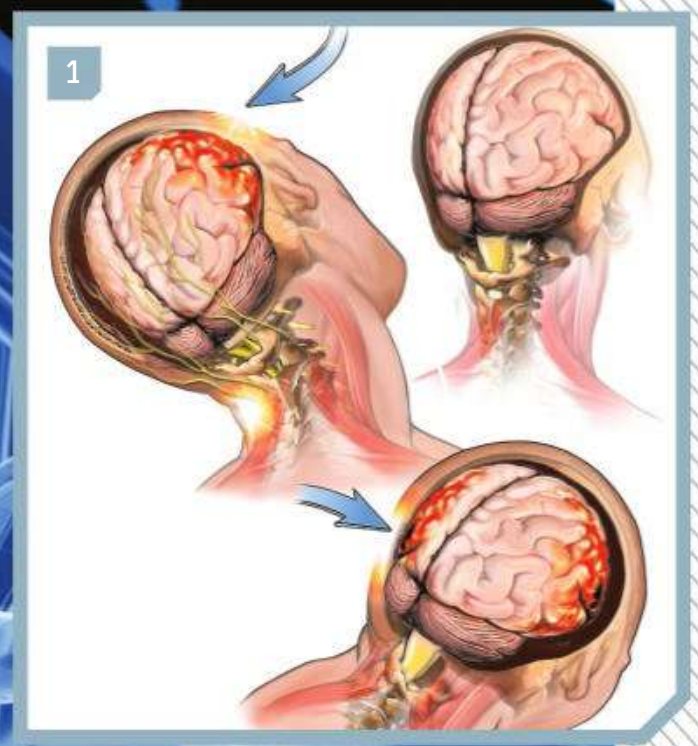
3 CRUMPLE ZONE
The front and back of a car have crumple zones that extend outwards from the passenger cabin. During an impact, these areas 'crumple' up and absorb as much of the impact as possible.

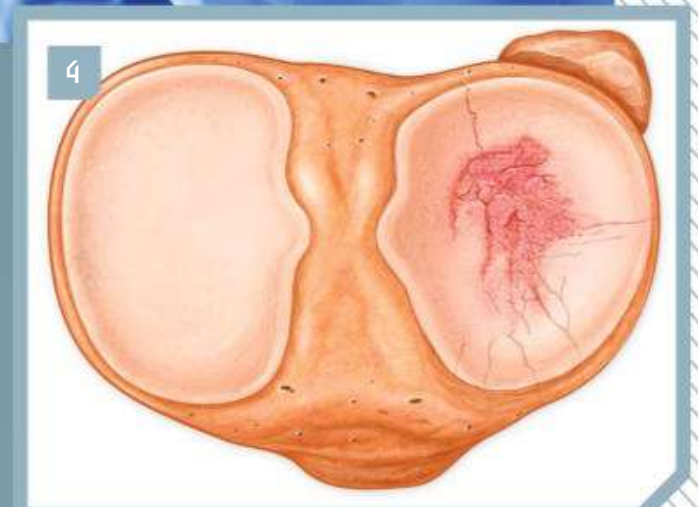
4 ANTI-LOCK BRAKING
When drivers hit the brakes suddenly, the wheels can lock, causing the vehicle to skid. Anti-lock brakes help regain control of the vehicle by constantly releasing and applying the brakes until the vehicle comes to a stop.

© Getty

IMPACT ON THE BODY

These are the most common injuries that result from road accidents





1 COUP-CONTRECOUP
Car crashes can cause high-impact head trauma such as coup-contrecoup injuries. This involves a head injury at the site of impact (coup) followed by an injury at the opposite side of the brain to the direct trauma (contrecoup). Both sides of the brain experience trauma when a sudden collision throws the head forwards then backwards.

2 WHIPLASH
When the head is thrust forwards during a crash before quickly being jolted back again, the muscles and ligaments in the neck are stretched and the soft tissue is injured.

3 RIB FRACTURES
The ribs can collide with the steering wheel during high-impact crashes. Fractures and breaks in these bones can cause breathing difficulties following a car accident.

4 KNOCKING THE KNEES
The knee only bends in one direction. This means that when extreme force is applied to the knee, the bones in the middle of the leg are at risk of fracturing. The tibia – a bone of the lower leg – faces the front of the car when a person sits in the vehicle, making it a common fracture site.

5 TRAUMATIC AORTIC INJURY
One of the major causes of car crash deaths is injury to the aorta. When a seat belt isn't worn properly, the force applied to the edge of the seat belt can create a tear in the body's largest artery as it cuts through the body.

6 SKIN BREAKS
Broken glass and other car crash debris cut the skin first. Collisions often result in stitches and sometimes skin grafts being required.

DID YOU KNOW? Car crash prevention technology could reduce fatal collisions by 30 per cent

CRASH PREVENTION

How the latest smart technology can predict and prevent a road collision

1 LANE DEPARTURE TRACKING

Cameras at the front of the car track the car's position in a lane. If the vehicle moves out of the lane without the driver indicating, a warning signal alerts the driver to return to the correct position on the road.

3 EMERGENCY BRAKING

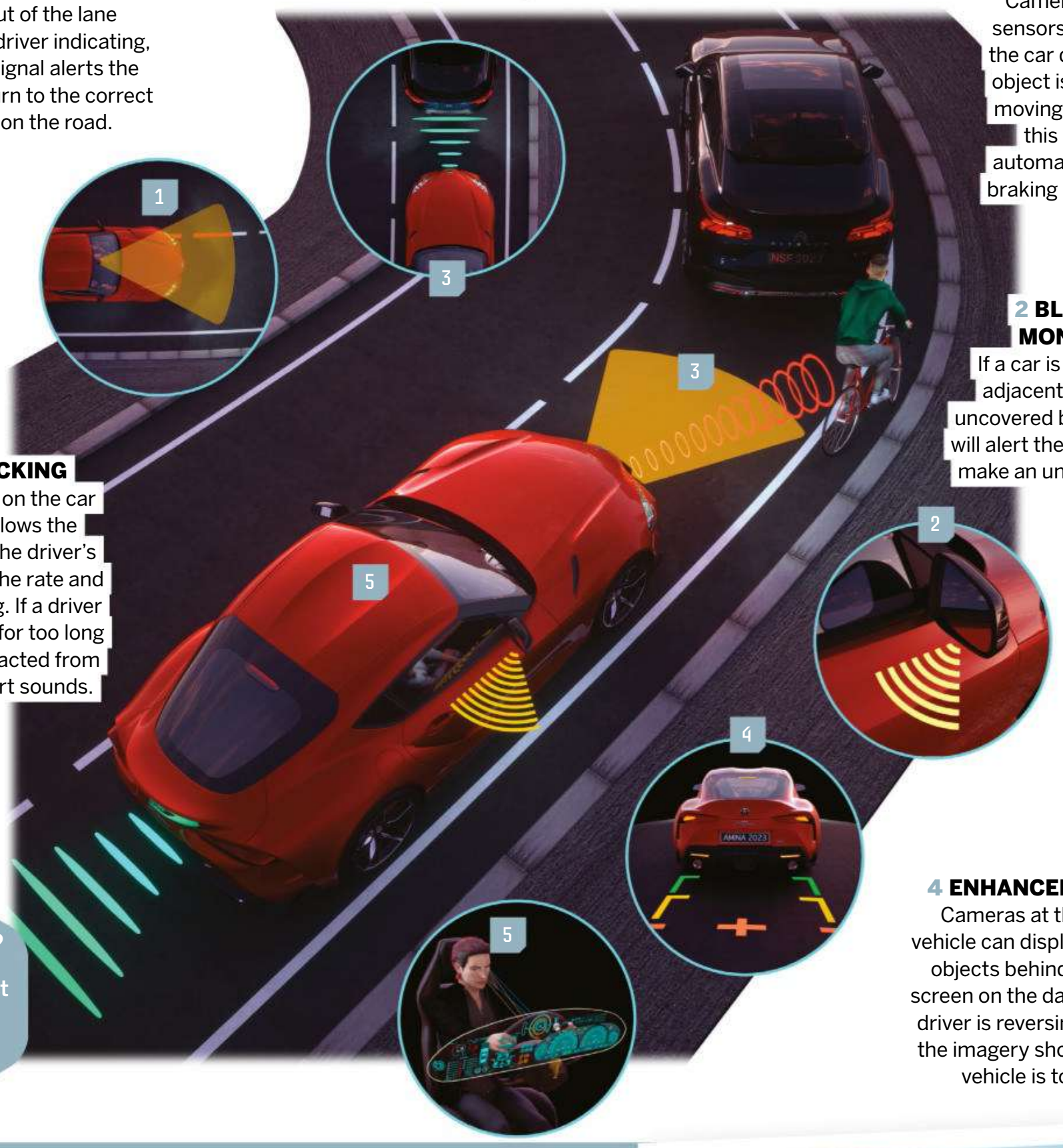
Cameras and radar sensors at the front of the car detect when an object is too close to a moving vehicle. When this is the case, automatic emergency braking can be applied.

2 BLIND SPOT MONITORING

If a car is travelling in the adjacent lane in an area uncovered by mirrors, the car will alert the driver before they make an unsafe lane change.

5 EYE TRACKING

A small camera on the car dashboard follows the movements of the driver's eyes, as well as the rate and speed of blinking. If a driver shuts their eyes for too long or appears distracted from the road, an alert sounds.



4 ENHANCED REAR VIEW

Cameras at the back of the vehicle can display a clear view of objects behind the car onto a screen on the dashboard. When a driver is reversing, guidelines on the imagery show how close the vehicle is to a collision.

Did you know?

Whiplash is most common in rear-end car crashes

SMARTPHONE SAVIOURS

When a severe car crash occurs, injured drivers and passengers may rely on nearby witnesses to call the emergency services. But what happens if a crash takes place on a deserted road and the car's occupants are unresponsive? Many modern smartphones are now equipped with crash-detection technology that utilises data such as the speed that the phone is travelling, sound levels and pressure changes to determine when a car crash has occurred. The iPhone 14 and latest Google Pixel phones will play an alarm when data predicts that there's been a crash and automatically send an alert to the emergency services. If it's a false alarm, the phone owner can swipe to disable the alert, but in an emergency situation the device shares the location with first responders so that there's a speedy response and a higher chance of survival for the crash victims.

As well as the emergency services, smartphones can be programmed to inform friends and family after a collision

© Alamy / Illustration by Nicholas Forder

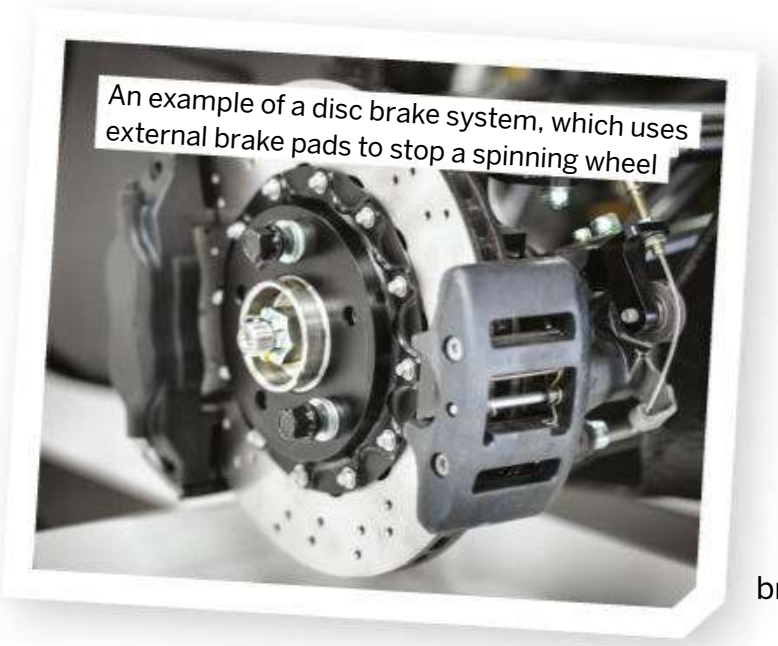
CAR BRAKES EXAMINED

How fluid dynamics keeps cars from crashing

WORDS **SCOTT DUTFIELD**

Mechanical braking systems were the norm from the beginning of the 20th century. Early systems used either wooden blocks to slow carriage wheels or cable-wrapped drums to slowly stop wheels from turning. However, the automotive industry was revolutionised when mechanical brakes were swapped for fluid ones. The concept of hydraulic brakes was proposed by American aviation engineer Malcolm Loughead in 1918. He discovered that when enough pressure was applied to a fluid, it could transfer that energy to the brake systems in early cars. Now, hydraulics are widely used to keep cars safe on the road.

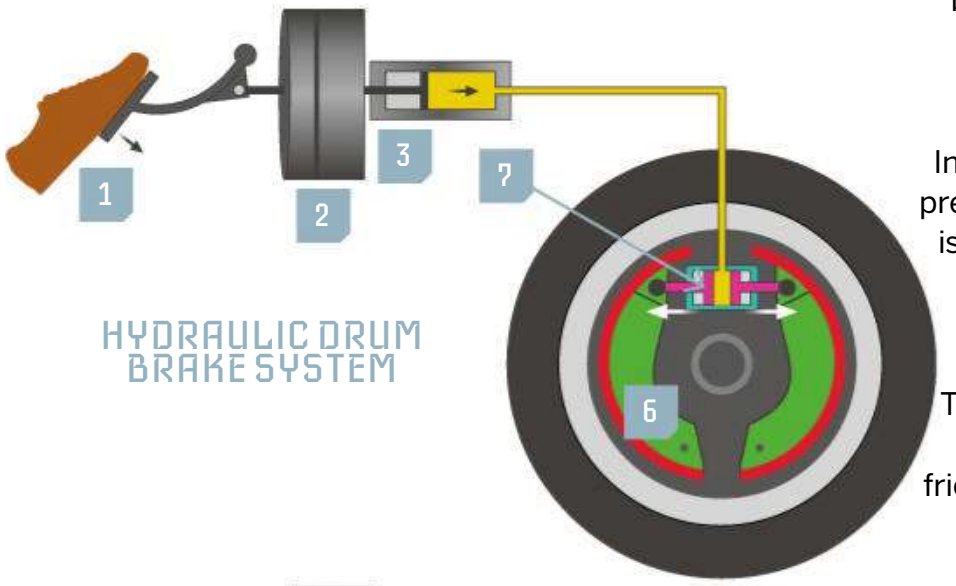
The success of hydraulic brakes relies on a principle in physics called Pascal's law, which states that when there's an increase in pressure at any point in a confined fluid, there is an equal increase at every other point in the container. A hydraulic braking system is made up of cylinders and tubes that are filled with braking fluid. When pressure is applied to the fluid within the system, delivered by a foot on a braking pedal, pressure is transferred to a set of brake pads that sit on a car's wheels. When the pressure increases on the fluid, it equally increases on the attached brake pads, which are pushed against the spinning wheels of the car. The fluid nature of this type of braking system allows the driver to gently apply the brake and smoothly reach a standstill.



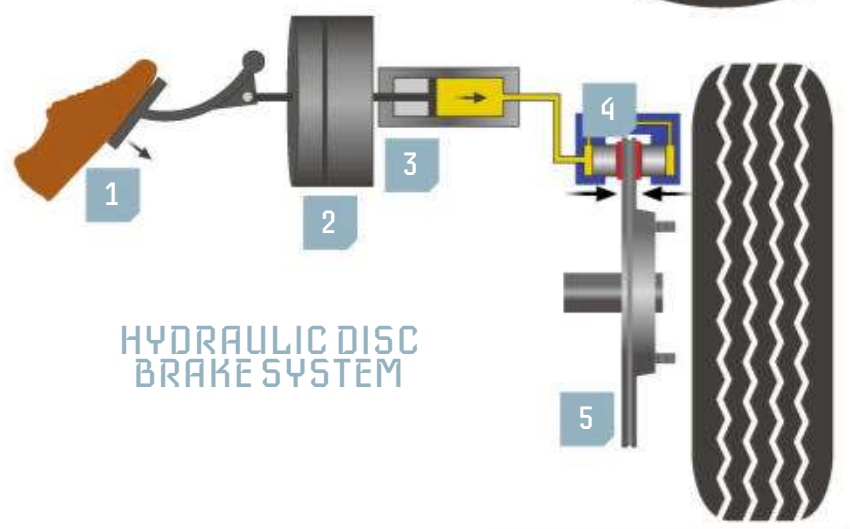
An example of a disc brake system, which uses external brake pads to stop a spinning wheel

HOW TO STOP A SPINNING WHEEL

Discover the two types of hydraulic brake systems that take the momentum out of cars



HYDRAULIC DRUM BRAKE SYSTEM



HYDRAULIC DISC BRAKE SYSTEM

Did you know?

Friction can cause brake discs to reach 137 degrees Celsius

1 PEDAL
To engage the car's hydraulic braking system, the driver presses down on a foot pedal.

2 VACUUM BRAKE BOOSTER
This metal chamber increases the force applied to the system by pushing out the air in the chamber, creating a vacuum.

3 PISTON
The forces created by the brake booster push a piston against pressurised brake fluid.

4 BRAKE PADS
In a disc brake rotor system, the pressure applied to the brake fluid is transferred to the brake pads against the wheel.

5 BRAKE DISC ROTOR
The brake pads clamp down on the brake disc rotor, creating friction and slowing the car down.

6 SHOE
Instead of brake pads, a drum brake system uses brake shoes that are pressed against the inside of a wheel drum to create friction and slow the car down.

7 PISTON
The brake piston connects the fluid cylinder to the brake pads on the brake shoes and applies pressure to them while braking.

USING THE HANDBRAKE

Every car's braking system comes with a backup plan, and that's the handbrake. To make sure the car doesn't roll away while parked or if the hydraulic braking system fails, the handbrake uses a completely mechanical system to keep the car stationary. The handbrake is attached to a sturdy metal cable which connects it to the car's rear-wheel brake discs or drums. When the handbrake lever is lifted, the cable is pulled. This will mechanically trigger the braking system through a series of levers, pulleys and guides to almost immediately bring the car to a stop or hold the wheel in place when parked. Electric handbrakes work on a similar basis but use electric motors to push against brake pads and hold them in place.

To prevent accidental handbraking, systems are fitted with a safety trigger that releases the lever

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				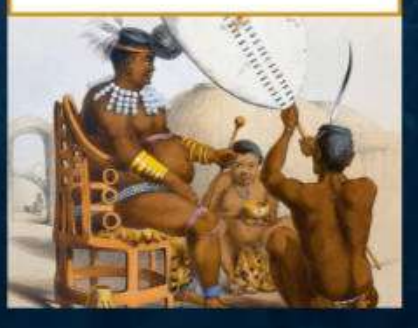

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SCIENCE

WHAT MAKES THINGS BIODEGRADABLE?

The chemistry and biology behind the natural breakdown of organic matter

WORDS **SCOTT DUTFIELD**

Most vegetables will decompose within a month

DID YOU KNOW? Despite being a natural fibre, it takes silk four years to even begin the process of biodegradation

The term ‘biodegradable’ is often used to describe a material’s ability to be broken down naturally by the environment through a process known as biodegradation. During this process, organic matter, such as that found in plants and animals, is torn apart, broken down and digested by fungi and microbes. What remains is a nutrient-rich biomass that fuels the growth of new plants and animals in a repeating and self-sustaining process – it’s quite literally the circle of life.

One of the most important aspects of biodegradation is the transfer of carbon. Often referred to simply as the carbon cycle, this natural undertaking helps regulate the planet’s temperature, as well as provide food and energy to its inhabitants. During the cycle, carbon is exchanged with oxygen in the atmosphere through plant photosynthesis, which is then stored in plant matter. That carbon is passed on to the animal that eats the plant, then to the animal that eats that animal, and so on, up through the food chain. When plants and animals die, that carbon is returned to the earth through biodegradation, whereby countless microorganisms chow down on organic matter, releasing carbon dioxide into the atmosphere to restart the cycle.

Outside of the natural order of things, the word ‘biodegradable’ is used as a label to describe products and packaging that are capable of undergoing the process of biodegradation, as opposed to non-biodegradable materials such as plastic, glass and metals. When we toss away our rubbish, it typically ends up in one of three places: an incinerator, landfill site or recycling centre. As the name suggests, incinerators torch waste and convert it into ash and gas, whereas recycling centres seek to transform materials into something useful. Landfill sites, on the other hand, are places where biodegradation can occur. It occurs under one of two conditions: aerobically, with the help of oxygen,

Did you know?

It takes chewing gum five years to biodegrade

A lack of oxygen inside a landfill site can make it difficult for material to decompose

CYCLING CARBON

How biodegradation puts carbon back into the earth to release it again

1 ORGANIC MATERIAL
Organic matter is filled with carbon atoms that are recycled into the environment through biodegradation.

2 DECOMPOSITION
Organic matter decomposes into smaller pieces, either through physical forces such as wind and rain or from living organisms in the soil, such as fungi and invertebrates.

3 DIGESTION
Over time, microbes such as bacteria finish off and metabolise what remains of the organic matter.

4 BYPRODUCTS
Once organic matter has been completely broken down and devoured, what remains are three byproducts: carbon dioxide, water and a carbon-rich substance called biomass.

5 ASSIMILATION
The byproducts of biodegradation are then assimilated back into the environment and used to promote the new growth of organic matter.

© Alamy / Illustration by Adrian Mann

Pseudomonas are one of the many groups of bacteria in the environment involved in the biodegradation process

Bioplastics are often used in food packaging and bags

5 MATERIALS THAT ARE BIODEGRADABLE

1 CARDBOARD
Around 72 million tonnes of cardboard is produced each year worldwide. Cardboard is made from natural fibres that take around two months to break down.

2 PAPER
Paper packaging takes around two to six weeks to decompose. A commonly recycled material, the cellulose fibres that make up paper can be recycled five to seven times before they become too weak to form paper.

3 BAMBOO
Made from the fast-growing bamboo plant (*Bambusa vulgaris*), this type of biodegradable material can become compost in up to six months.

4 CORNSTARCH
As a replacement for polystyrene peanuts, cornstarch packing peanuts take around 90 days to decompose and even dissolve in water.

5 ORGANIC FABRIC
Organic materials such as cotton or hemp biodegrade at different rates. Cottons may take several months to decompose, whereas hemp takes only a couple of weeks.

or anaerobically, without oxygen. Because of the compacted structure of a landfill site, biodegradation often occurs anaerobically, the slowest of the two conditions. Some studies have found that food items such as grapes and corn cobs are still recognisable 25 years after entering a landfill. Meanwhile, in an oxygen-rich compostable environment, it would take only weeks for them to decompose.

The phrase biodegradable is often used interchangeably with compostable, but the two are very different. For a product or material to be considered compostable there needs to be no harmful chemicals or substances that release during the process of biodegradation. There are some instances where materials such as plastics are classed as biodegradable, but in the process they release toxic chemicals into the environment.

Each year we produce around 380 million tonnes of non-biodegradable plastics, and only 50 per cent of this is recycled. Traditional petroleum-based plastics are made from oils and gases that form robust molecular chains called polymers. These chains are so robust that they are unable to be broken down through biodegradation alone. However, some biodegradable plastics are more environmentally friendly.

Bioplastics and biodegradable plastics are two different things. Bioplastics are made from natural plant matter that's usually chemically treated to form strong polymer plastics called polylactic acid or polylactide.

Though biodegradable plastics still use raw materials such as oil, different chemicals are added that allow the plastic to 'biodegrade' in the right circumstances, such as in high temperatures and under ultraviolet light. Although biodegradable plastics will break down much faster than the non-biodegradable versions, taking between three and six months, they release harmful chemicals and substances into the environment if they are not disposed of correctly. Bioplastics, on the other hand, release no such toxic chemicals. In the same way that organic materials shed carbon during decomposition, bioplastics also release carbon stored in the plant matter within them. Despite the risk to the environment, the popularity of bioplastics has struggled to match that of non-biodegradable alternatives. In 2022, only 1,142 tonnes of bioplastics were produced globally.

Did you know?
10 million tonnes of plastic reaches the ocean each year

BIODEGRADABLE GLASS

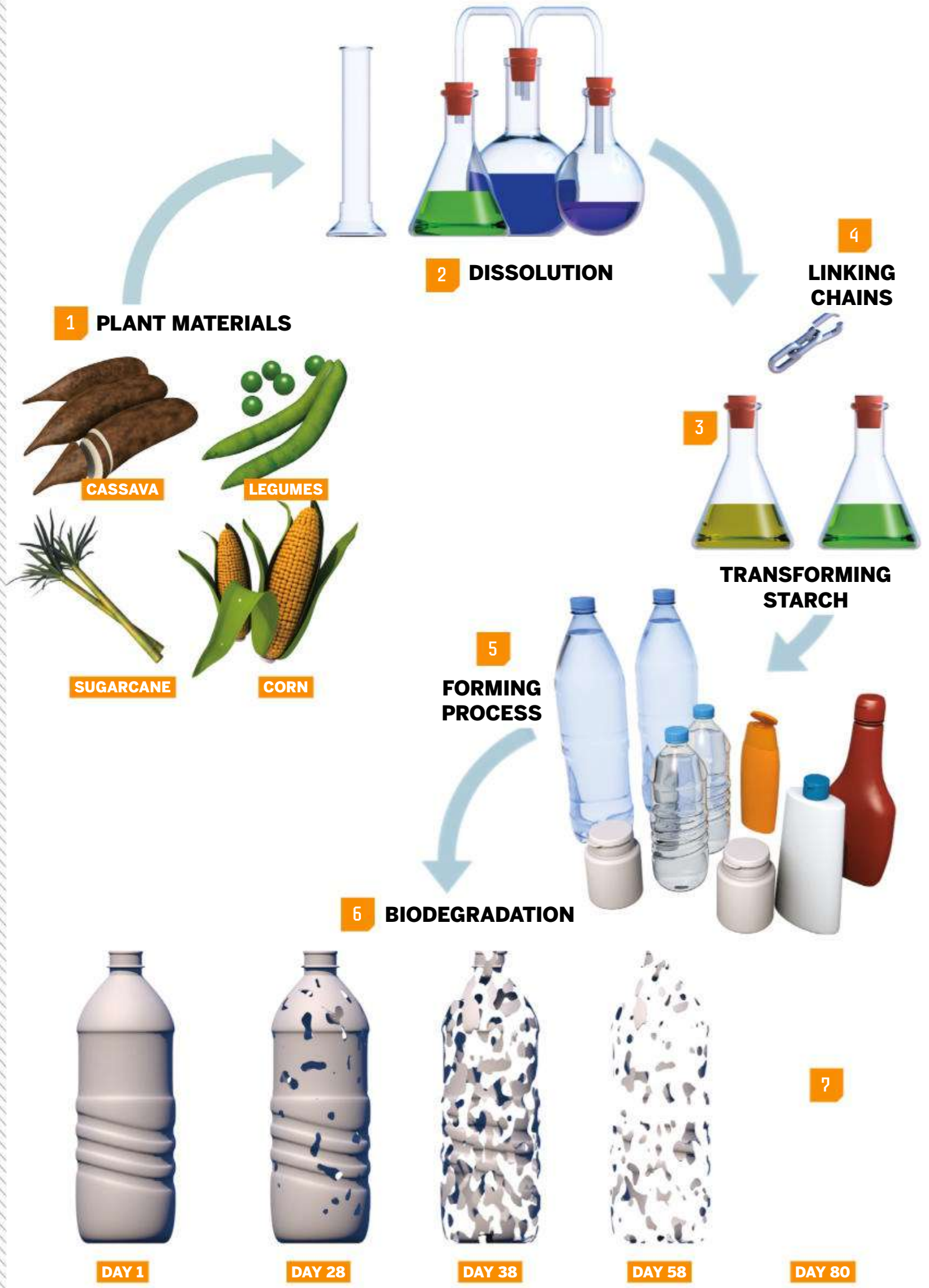
Glass is typically made by heating natural raw materials such as sand or limestone. As a rigid non-biodegradable material, the only way glass can break down in the environment is through physical forces such as wind and water, which can take up to 4,000 years. In March 2023, researchers at the Chinese Academy of Sciences created an experimental glass made from modified amino acids and peptides. In the novel method, amino acids are heated and subjected to a supercooling treatment, then doused in water, rapidly forming a clear, glass-like material. When put to the biodegradability test, researchers discovered that the new glass material was broken down by microbes in soil within around three to seven months. Glass beads were also ingested by mouse subjects without causing harm and appeared to biodegrade in the body, suggesting there's scope for its use in drug delivery.

Advancements in bioglass could one day provide a new delivery system for medicines

DID YOU KNOW? It's estimated that a typical glass bottle will take around a million years to biodegrade

GROWING PLASTIC

How bioplastics are chemically engineered from crop plants



1 PLANT MATERIALS
The building blocks for bioplastics come from natural sources such as corn, legumes, cassava and sugarcane.

2 DISSOLUTION
Plant matter is broken down into starch, proteins and fibres using different acids.

3 TRANSFORMING STARCH
The starch is then separated from the rest of the solution, fermented and turned into lactic acid.

4 LINKING CHAINS
Starch is made up of lots of carbon chains, similar to those found in non-biodegradable plastics.

5 FORMING PROCESS
The long molecule chains of lactic acid are injected into a mould and heated to set them into the desired shape.

6 BIODEGRADATION
Microorganisms are able to break down bioplastics naturally, releasing carbon dioxide, water and biomass in the process.

7 GOING, GOING, GONE
Bioplastics take around 12 weeks to break down.

© Alamy / Getty / Illustration by Adrian Mann

People say that you never forget how to ride a bike

WHAT IS MUSCLE MEMORY?

How neural shortcuts in your brain make practised activities feel familiar

WORDS **AILSA HARVEY**

When you move from one side of the room to the other, how much do you analyse the action? For most people, the series of muscle movements that allow them to get around on a daily basis is automatic. But when babies are born, their brains haven't formed the neural connection with their walking muscles in order to stand and balance. Through trial and error, they begin to master walking on two feet. Eventually, when they've discovered the movements required for walking, the neural pathways are fully formed. From this point onwards, walking becomes a natural motion that requires little conscious thought.

Have you ever learned to ride a bike, play tunes on an instrument or mastered a sport over several years? Now that you have these skills, they're unlikely to suddenly vanish. For example, you might not have ridden a bike for several years, but you'll still be able to ride one and stay in control of it with no additional lessons or guidance. Despite being called muscle memory, the body part responsible for retaining these skills is the brain. A region of the brain called the motor cortex sends signals to the muscles needed for each skill, with precise instructions to execute physical movements with accuracy. The more these signals are delivered through messenger nerve cells called neurons, the smoother each resulting action is. When these become stored in your long-term memory, skill-based memories like riding a bike are recalled as soon as you sit in the saddle.

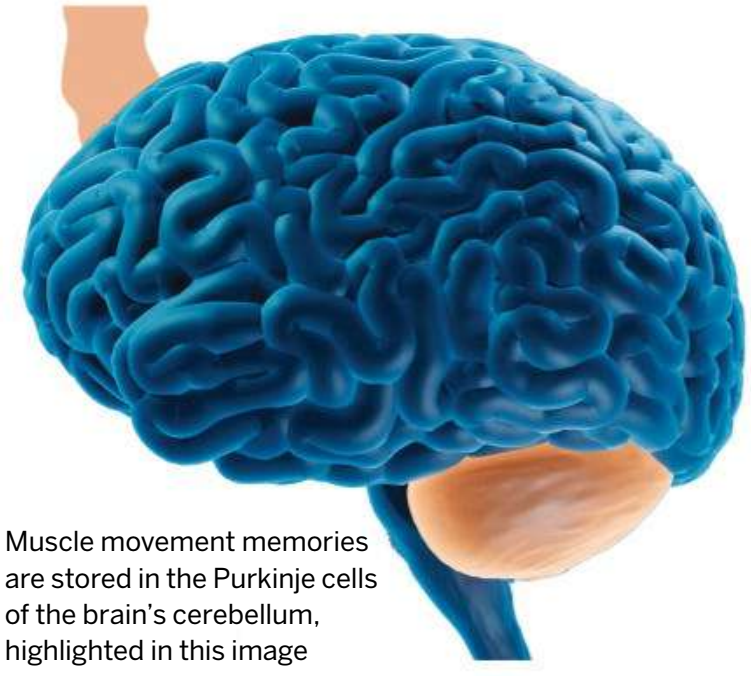
Did you know?

Muscle mass is built back quicker in those who work out regularly

1 LONG-TERM MEMORY
The brain stores repeated movements in long-term memory. This means muscle movements can be performed with little thought.

7 MYOSIN
These proteins in the muscles create force that gives the muscles strength to lift, push or pull.

8 ACTIN FILAMENT
This protein filament is a mechanical component of the muscle that guides the direction of contractions as it slides along the myosin filament. After repetitive contractions, such as in weightlifting, the number of actin filaments in the muscles used increases.



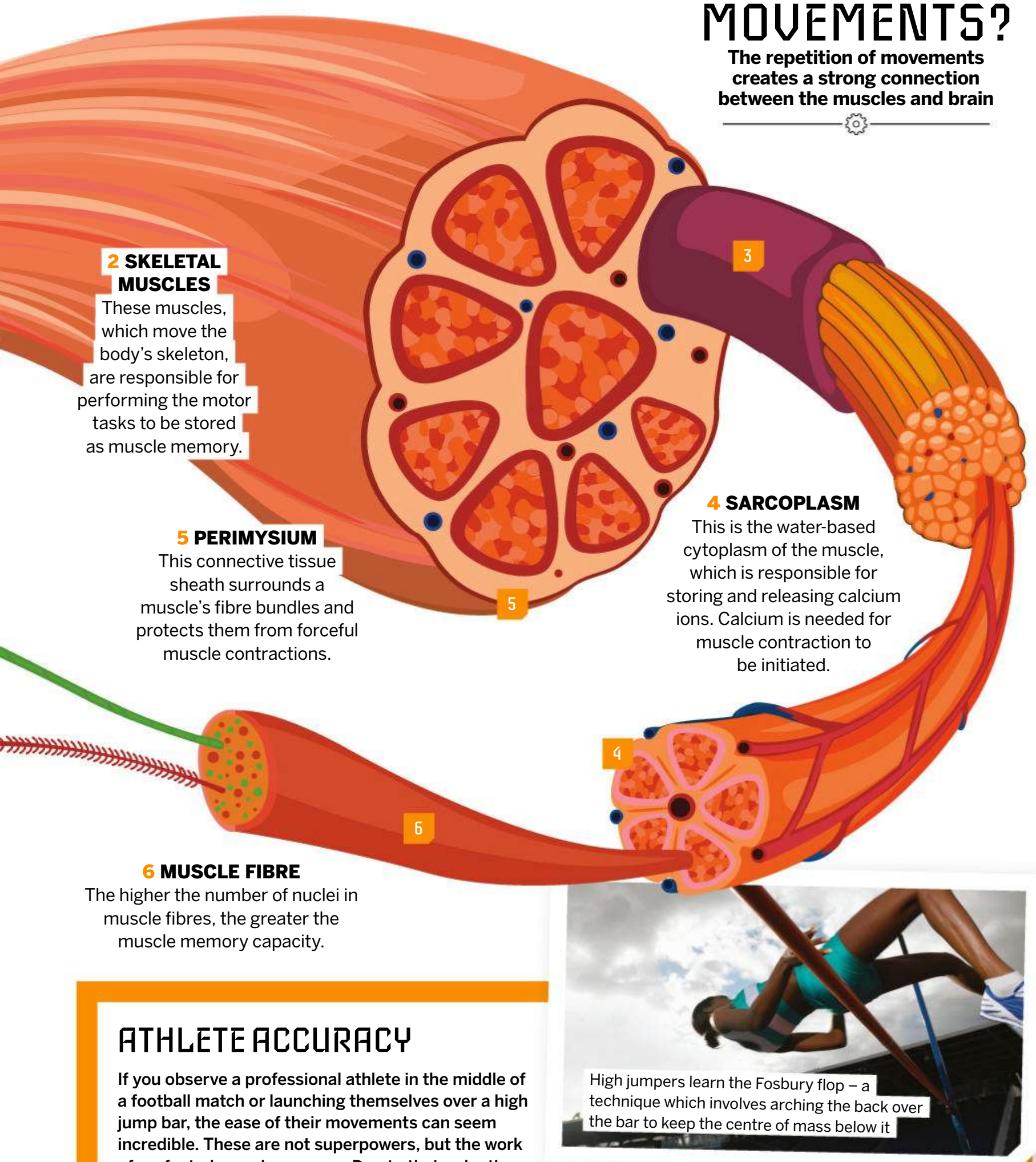
Muscle movement memories are stored in the Purkinje cells of the brain's cerebellum, highlighted in this image

DID YOU KNOW? Right-handed guitar players have stronger muscle memory for controlling strings in their left hand

HOW DO MUSCLES 'REMEMBER' MOVEMENTS?

The repetition of movements creates a strong connection between the muscles and brain

3 FASCICULUS
Bundles of nerve fibre strands in the muscles connect to the central nervous system and relay signals from the brain to muscles.



2 SKELETAL MUSCLES
These muscles, which move the body's skeleton, are responsible for performing the motor tasks to be stored as muscle memory.

5 PERIMYSIUM
This connective tissue sheath surrounds a muscle's fibre bundles and protects them from forceful muscle contractions.

4 SARCOPLASM
This is the water-based cytoplasm of the muscle, which is responsible for storing and releasing calcium ions. Calcium is needed for muscle contraction to be initiated.

6 MUSCLE FIBRE
The higher the number of nuclei in muscle fibres, the greater the muscle memory capacity.

High jumpers learn the Fosbury flop – a technique which involves arching the back over the bar to keep the centre of mass below it

ATHLETE ACCURACY

If you observe a professional athlete in the middle of a football match or launching themselves over a high jump bar, the ease of their movements can seem incredible. These are not superpowers, but the work of perfected muscle memory. Due to their relentless training schedules, the muscles that they need to control the dribble of a ball or expertly arch themselves over obstacles in athletics are almost preprogrammed. The strong neural connections that they have made to connect their mind and the rest of their body mean that while the brain focuses on the tactics of the competition, the body can perform complex moves without much conscious thought. An additional benefit to muscle memory in professional sportspeople is that it allows them to take breaks from the sport. Even though they may lose fitness during off-season months, not long after returning to training, their muscles can bounce back to the work they were previously trained for.

5 MUSCLE MEMORY TACTICS TO TRY

1 PRIORITISE PRACTICE
Practise your new sport or skill in regular and short training sessions. The more your brain is exposed to muscle patterns, the quicker it will remember and master them.

2 AVOID BAD HABITS
Muscle memory can arise in any movement. Make sure you don't pick up bad habits or your brain will hold onto these and you will naturally use these techniques.

3 SKILL BREAKDOWN
Different skills can involve a series of complex movements. Focus on each element of the movement first to make them easier to combine correctly.

4 SWITCH UP THE ENVIRONMENT
When training in the same place or environment, you can limit your muscle memory. To make sure your muscles are firing correctly in different scenarios, don't make every practice session identical.

5 TAKE YOUR TIME
Nobody becomes an expert overnight. Muscle memory relies on consistency and long-term repetition.

© Getty / Alamy

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A: FELIDAE **B:** CANIDAE **C:** BOVIDAE

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IS 'MUSCLE MEMORY' A REAL THING?
DOGS' EYES EVOLVED TO MAKE US LOVE THEM
THEY CAN SMELL IN 3D
CATS CAN HEAR HIGHER FREQUENCIES THAN DOGS
THEIR EYES EVOLVED FOR BETTER HUNTING
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BRAINDUMP

Amazing answers to your curious questions

How did wolves evolve into so many species of dog?

Russell Foster

People began to domesticate wolves at least 12,000 years ago, and probably in several parts of the world. Wolves would have been attracted to Stone Age human encampments by food, and by taking in and bringing up puppies people found, they could tame the animals and use them for their own ends. The diversity of dog breeds came about by a process of selective breeding, the same as that still used today – breeding from animals that had desired characteristics like tameness, obedience, speed or different shapes and sizes. For example, the dachshund, meaning badger-dog in German, is long and thin to go down holes in search of badgers. By selecting the most favourable individuals to breed the next generation, gradually across many generations, the desired form was achieved. Different breeds were developed in each region and between regions of the world, multiplying the number of varieties. It was a form of evolution, producing genetic change by a process of selection analogous – as Darwin recognised – to evolution in the wild, but with humans doing the selecting rather than the natural environment.

Did you know?
There are around 360 purebred dog breeds

WHAT ARE PINECONES? ARE THEY LARGE SEEDS?

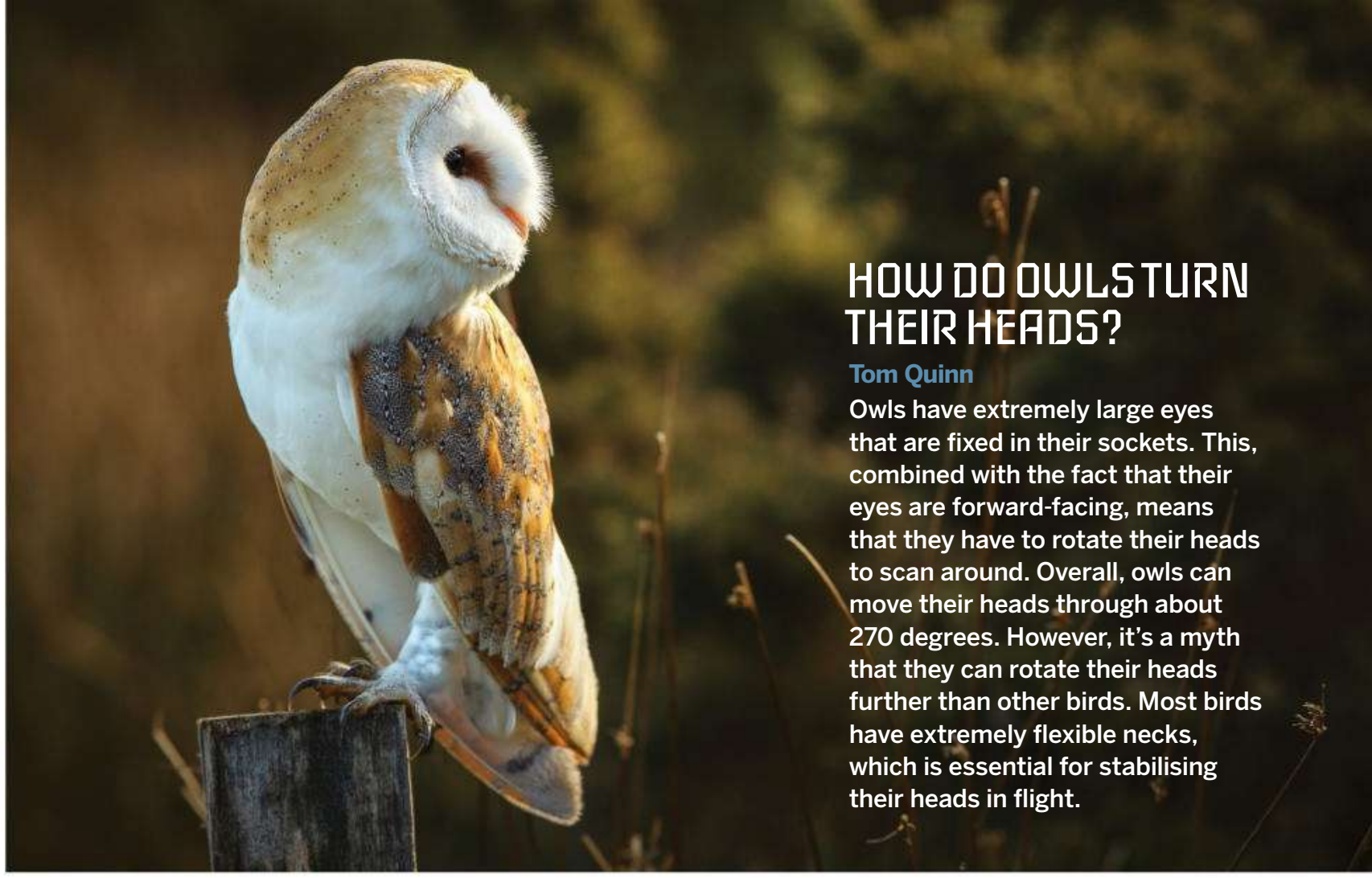
Mark Burr

Pinecones contain the reproductive structures of the tree. A female cone produces seeds and a male cone produces pollen. The female cone is the large woody one that people are more likely to be familiar with. Its scales become seeds when fertilised from pollen from the less conspicuous male cones. The male cones are very similar among all species of conifers, whereas the female cones are more varied, making them the ideal way to identify the species. Pinecone scales overlap each other like fish scales to protect the seeds.

HOW ARE COINS MADE?

Jim Crooks

Coins can be made in three different ways: casting from moulds, striking by hand and using machinery. Casting techniques were generally limited to the earliest issues, except in East Asia. Hand production involved placing hot metal blanks between two engraved dies and hammering them together to produce two-sided coins. In the West, mechanised production began in the 16th century, but the tremendous scientific and industrial progress of the 18th and 19th centuries, with the introduction of steam power, revolutionised coin production. The 21st-century mint is almost fully automated, including computer software and computer-aided manufacture for designing and cutting dies for coins.



HOW DO OWLS TURN THEIR HEADS?

Tom Quinn

Owls have extremely large eyes that are fixed in their sockets. This, combined with the fact that their eyes are forward-facing, means that they have to rotate their heads to scan around. Overall, owls can move their heads through about 270 degrees. However, it's a myth that they can rotate their heads further than other birds. Most birds have extremely flexible necks, which is essential for stabilising their heads in flight.

WHAT IS NESTOR'S CUP AND WHY IS IT SUCH A SIGNIFICANT HISTORICAL ARTEFACT?

Robert Patel

Nestor's Cup is a gold two-handled drinking vessel shaped rather like a tankard, and it has doves on the rim. It was found in Grave IV in a shaft grave in Grave Circle A at Mycenae in Greece by Heinrich Schliemann. It was given this title because it matches the description of a similar cup in Homer's *Iliad*. It was said that only Nestor was strong enough to pick it up and drink from it. The shaft graves date to 1600 to 1500 BCE, and there's every likelihood that the spectacular grave goods found there belonged to the rulers of Mycenae.

What's the hardiest species of rose?

Lynette Cole

Rugosa roses are a very hardy species of rose, often known as the rugged rose. They grow aggressively and can survive very cold temperatures, salt air, drought, shade and poor soil. They are also highly disease resistant. Rugosa roses have wrinkled leathery leaves, and the word 'rugosa' means wrinkled in Latin. They are big roses, often growing up to 1.5 metres or more, and come in a variety of colours with a beautiful perfume.

© Alamy / Getty

DID NERO PLAY THE FIDDLE WHILE ROME BURNED?

Annalise Rojas

This myth stems from the Roman historian Gaius Suetonius Tranquillus, who wrote that Nero himself ordered the fire and that while it ravaged the city he sang while playing his musical instrument. This placement of blame at Nero's feet appears to come from his vilification of Christians – of which Suetonius condemned in his writing – and his general reputation as a mad, tyrannical dictator. Importantly, however, while much of what Suetonius reports is ratified in other historical sources, Nero playing a fiddle while Rome burned appears to be inaccurate.

Firstly, as for playing the fiddle – which wasn't invented until roughly 1,000 years after his death – Nero is reported to be a player of the lyre, an instrument invented by the ancient Greeks. Secondly, far from being in Rome during this cataclysmic event, other authoritative sources – such as Tacitus, the foremost Roman historian – place Nero in the city of Antium at the time. Thirdly, Tacitus reports that Nero rushed back to Rome upon hearing the news to organise a relief effort and open his palaces to provide shelter for the homeless. Despite these accounts, however, the myth remains.

Is it true that ferns are an incredibly ancient species of plant?

John Niven

Yes, it's true. Ferns are a very ancient family of plants, are fast growing and were a good source of food for dinosaurs. The earliest ones date from around 360 million years ago. Ferns looked a bit different back then: ancient ferns had tree-like trunks with delicate fronds – their leafy branches – but some of today's ferns still have characteristics which would help them survive in those primeval swamps, like the rough tree fern (*Cyathea australis*), with its scaly and fibrous trunk and canopy of lengthy, intricate leaves that thrive in the shade. Although some species are now extinct, others are still around to this day.

HOW DOES THE BUS INFORMATION SYSTEM WORK?

Mohammed Jabi

iBus keeps track of where London's buses are, allowing controllers to regulate services and make them more reliable. It uses a combination of technologies, including GPS satellite technology. The bus data radio sends the location of the bus about every 30 seconds to a central computer system. This system passes data to service controllers who maintain bus performance along the route and also predict arrival times so passengers can get information through the system at select bus stops.

HOW DO FISH GILLS WORK?

Mark Wrangham

Like humans, fish need oxygen to survive, but unlike us, they are capable of getting the oxygen they need from water. To do this they use an arrangement of filaments on either side of their neck called gills. Fish gulp in oxygenated water, force it through their gills and then out through the gill openings while also continually pumping deoxygenated blood from the body into the gill filaments. As the oxygenated water passes by the deoxygenated blood, oxygen diffuses into the gills. Efficiency is increased by the blood and water flowing in opposite directions – this is known as a counter-current exchange mechanism. Using this, a fish can extract up to 70 per cent of the oxygen dissolved in the water. Waste products in the blood can also be removed from the blood by the same process, passing from the gills into the water.

Did you know?
Dinosaur means 'terrible lizard'

Which species of dinosaur would have lived in the British Isles 70 million years ago?

Nikolaos Kokkinos

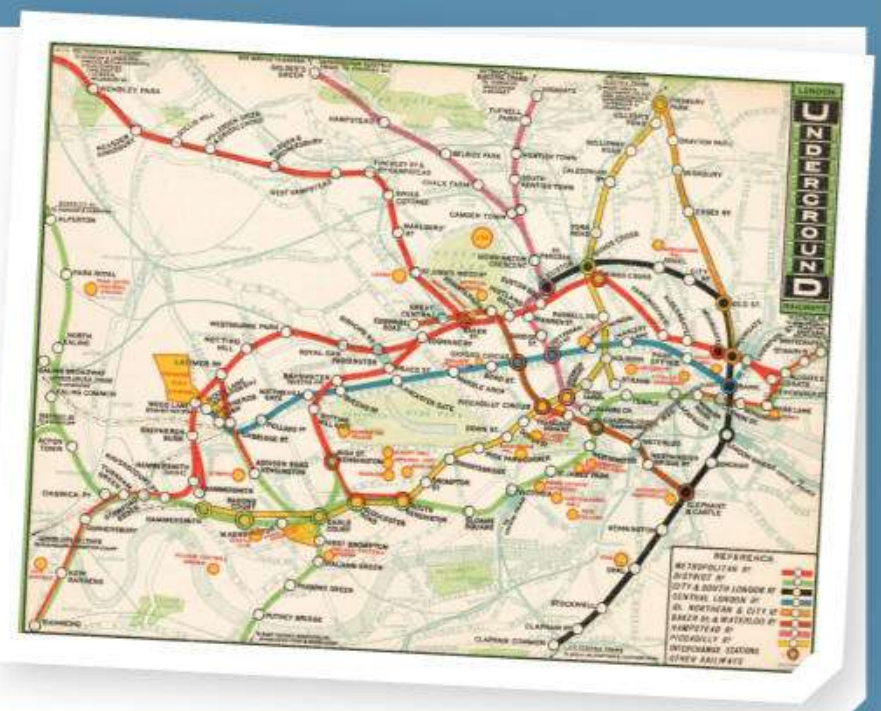
Only two dinosaurs are known to have been in Britain 70 million years ago from evidence – incomplete remains of an armoured dinosaur called *Acanthopholis* and a single tooth of a duck-billed dinosaur, both from chalk rock in southern England. In that era, the land that makes up the British Isles was isolated from Europe and North America and mostly covered by seas.

Marine sediments that turned into chalk rocks were laid down in southern England, and the two dinosaur records provide evidence that at least one hadrosaur and one ankylosaur were living on the land areas. There were many dinosaurs living in North America 70 million years ago, and quite a few in Europe.

HOW DOES THE TUBE MAP COMPARE WITH A STREET MAP OF LONDON?

Jessica Hunter

Early Underground maps were geographic, showing passengers where they were in relation to the streets above. As the network grew, the maps had to include more information. Attempts to fit in the extremities of each line resulted in a very crowded central area, making the map hard to read. In 1931, draughtsman Harry Beck designed a new map which dispensed with geographical accuracy. The aim of this diagrammatic map was to accommodate the whole network and make it easy to read. The dense central area was enlarged in relation to the outlying areas, allowing both to be shown more clearly. The design was first introduced in 1933 and was an immediate success. Metros all over the world now use similar designs. The Tube map is still one of London's most recognisable icons.



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Did you know?
Monitor lizards are native to Africa, Asia and Oceania

Why do monitor lizards flick their tongues out so frequently?

Janine Blackman

Monitor lizards, like snakes, have a pair of sensory organs located above the roof of the mouth called the vomeronasal or Jacobson's organ. This organ is used to detect scent particles within the air. These lizards continuously flick their forked tongues to collect these particles and to 'taste' the air; this extra sense is used mainly for hunting, as monitor lizards are very active predators and are almost constantly foraging around for food. During the breeding season, it's also used to help these usually solitary reptiles find a mate; the male will use his tongue to follow the scent of a female.

WHAT'S THE LARGEST SPECIES OF TREE NATIVE TO BRITAIN?

Jenny Watkin

Two trees can claim to be the largest in Britain: the oak and the yew. Both can live to a great age and have very large trunks with a wide girth. The Fortingall Yew in Scotland is 3,000 to 9,000 years old, and at its prime in 1769 was over 16 metres in diameter.

HOW DO GLOWWORMS GLOW?

Harry Blythe

Glowworms, a disparate nomenclature for a dissimilar collection of insects – none are actual worms – glow via a variety of different methods, but all emit light via bioluminescence. Bioluminescence is a naturally occurring form of chemiluminescence where energy is released by a chemical reaction in the form of light. For example, in *Phengodes* a glow is produced and emitted from giant solitary cells within the abdomen, while in *Arachnocampa* it's emitted through modified excretory organs. In addition, glowworm bioluminescent organs vary widely in size, location and structure, indicating that the different species' glowing abilities evolved independently of one another. This is supported by the reasons for producing the glow, which range from attracting a mate through to warding off predators and luring prey into sticky webs for consumption – the latter characteristic of the *platyura* species.

SOMEONE TOLD ME THAT LONDON HAD CABLE CARS ONCE, LIKE SAN FRANCISCO. IS THAT TRUE?

Teodor Kovalchuk

There were two cable tramways in London. The first, which was also the first in Europe, opened in May 1884, running from the Archway Tavern in north London up the steep Highgate Hill to Highgate Village. The initiator was Andrew Smith Hallidie of San Francisco, who achieved fame for manufacturing wire rope. He was keen to export his pioneering cable car design beyond America, and with the aid of Sir Sydney Waterlow, a former Lord Mayor of London, the Highgate Hill project took shape. The system worked by using a continuous wire rope sunk into the road between the tracks, hauled by a winch in a winding house and depot. The cars had a gripper mechanism that attached to the rope, moving, in the case of Highgate Hill, at a steady six miles per hour. The Highgate line closed in 1909. The other line, between Kennington and Streatham, ran from 1892 to 1904.

WHO OR WHAT CONTROLS THE TRAFFIC NETWORK IN LONDON?

Peter Freestone

Smoothing London's traffic takes a lot of coordination between Transport for London (TfL), the London boroughs and the capital's traffic signal sites. The London Streets Traffic Control Centre, managed by TfL, works to manage traffic flow across the capital. By reducing the duration of unplanned congestion in real time, TfL can ensure that London's roads remain clear of obstructions, helping cars, buses, cyclists and pedestrians travel more smoothly. Traffic lights are regularly reviewed to improve efficiency at junctions and intelligent technology has been introduced at many sites to allow traffic lights to monitor traffic levels and adjust their own timings accordingly. More than half of the traffic signals in London can be directly controlled by the Traffic Control Centre, enabling TfL to better manage traffic across London.

What is a coelacanth?

Jack Truss

Coelacanths are lobe-finned bony fish that first evolved 400 million years ago and were thought to have gone extinct between 65 and 100 million years ago. One living coelacanth was discovered in 1938 off the coast of South Africa, and a second species was found in 1998 along the coast of Indonesia. The coelacanth has been nicknamed a 'living fossil' because its fossils were found before a live specimen. There are several characteristics that distinguish the coelacanth from other fleshy-finned fish. They have a three-lobed caudal fin, a secondary tail that extends past the primary tail and special 'cosmoid scales', forming a thick protective armour. A hinge at the back of the skull allows the coelacanth to gape its mouth wide quickly, and their backbones are hollow, giving them their name, which translates to 'hollow spine'.

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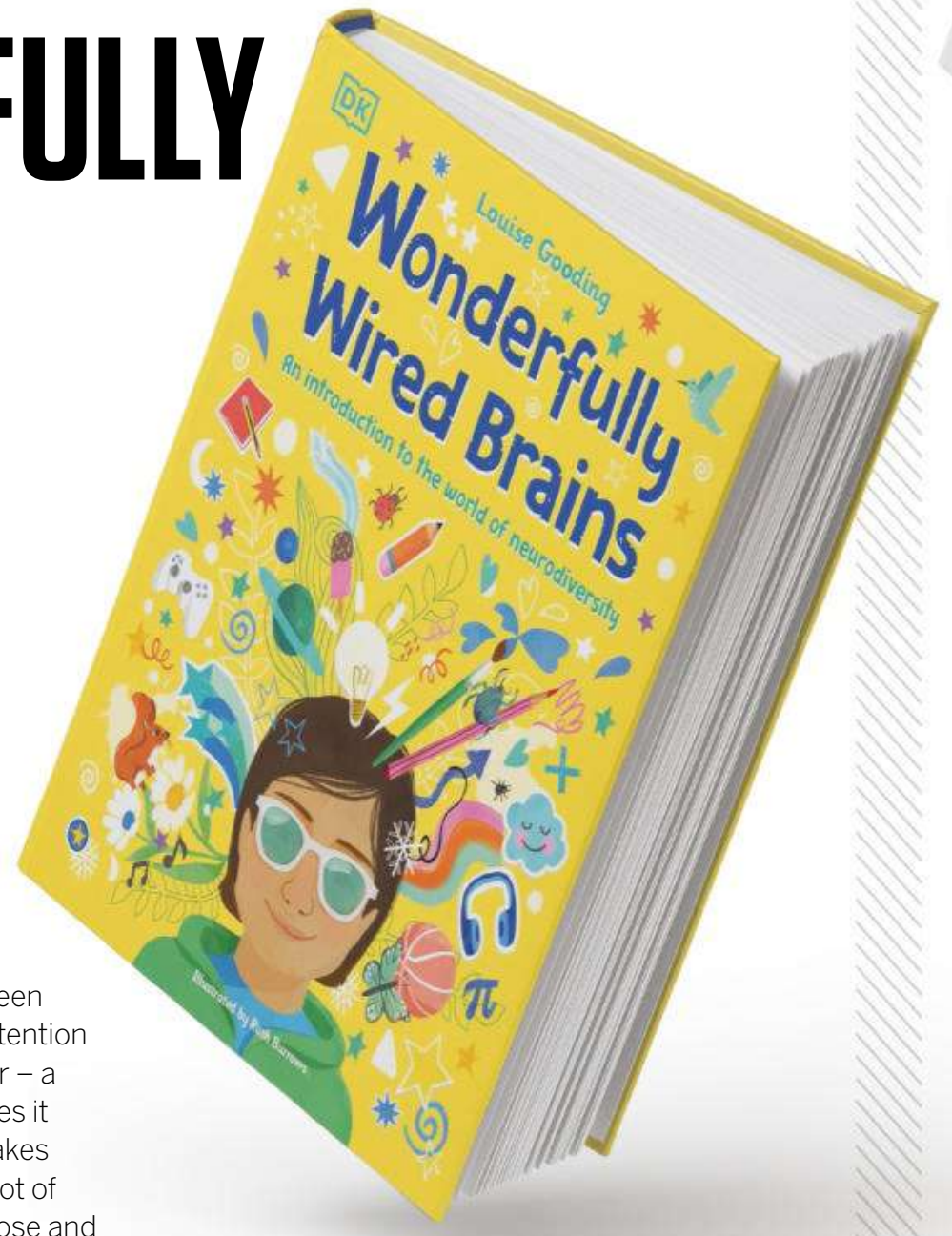
The latest book releases for curious minds



WONDERFULLY WIRED BRAINS

AN INTRODUCTION TO THE WORLD OF NEURODIVERSITY

AUTHOR **LOUISE GOODING**
ILLUSTRATOR **RUTH BURROWS**
PUBLISHER **DORLING KINDERSLEY**
PRICE **£12.99 / $16.99**
RELEASE **OUT NOW**

Author Louise Gooding has been diagnosed with ADHD, or attention deficit hyperactivity disorder – a condition that typically makes it difficult for someone to concentrate, makes them fidgety and seem like they have a lot of nervous energy - or a combination of those and other traits. She points out that "if you have met someone with ADHD, you have really only met one person with ADHD." So does her diagnosis make her the ideal writer for *Wonderfully Wired Brains*, a book about neurotypical and neurodiverse brains? It certainly gives her insight into ADHD and an understanding that every individual's brain is wired differently. She respects that no two neurodivergent diagnoses are the same, regardless of the label the doctor has given them.

Wonderfully Wired Brains tries to make sense of autism, dyspraxia, dyslexia and other forms of neurodiversity, many of which have been boiled down into acronyms and abbreviations that have lost some of their meaning over the years. Gooding talks about these conditions, their bells, whistles, warts and all – a compound metaphor that someone diagnosed with a language processing disorder (LPD) might struggle to understand. The book begins with a simple introduction to our brains, their varied and layered functions and how even the cleverest of today's neuroscientists still know as much about our brains as astronomers know the entire universe. That's to give the reader – young and old – some perspective and context for what's to come. The next chapter details what it means to be neurodiverse and how people deal with their various symptoms in society. It's nicely rounded off with some history, including brilliant brains who may have been described as neurodiverse if they were born today, like musical genius Mozart and Crimean nurse Florence Nightingale. Finally, *Wonderfully Wired Brains* talks about today's neurodiverse achievers, like Olympic swimmer Michael Phelps, who credits his ADHD with helping him secure 23 gold medals. Or Osmo Tapio Räihälä, the award-winning composer whose synesthesia allows him to see sounds as shapes and colours.

Wonderfully Wired Brains is written and illustrated with children in mind, but it'll be an eye-opening read for any adults who want to understand more about the glorious spectrum of neurodiversity.

"It tries to make sense of autism, dyspraxia, dyslexia and other forms of neurodiversity"

EINSTEIN

A GRAPHIC BIOGRAPHY OF ONE OF THE GREATEST MINDS IN HISTORY

AUTHOR **JIM OTTAVIANI**
ILLUSTRATOR **JEREL DYE**
PUBLISHER **ROARING BROOK PRESS**
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Meet the man that changed the way we view the universe and follow his journey through life, love and science. *Einstein* isn't your typical biography. Rather than flicking through pages of text and constructing a person's life with your imagination, here the story of Albert Einstein is told through illustration as a graphic novel. As the story evolves from Einstein's early days in the late 1800s up to his death in 1955, illustrator Jerel Dye brings the physicist's world to life through his incredibly detailed artwork.

For his contributions to science, Einstein's name is now synonymous with genius, but his personal life is less well known. This book takes a look at the life behind the brilliance in a continual narrative, jumping between distinct milestones and achievements. *Einstein* is an excellent way to introduce a teenage audience to one of the world's greatest minds.

THE SECRET LIFE OF A WOODLAND HABITAT

DISCOVER UK WILDLIFE THROUGH THE SEASONS

AUTHOR **CHLOÉ VALERIE HARMSWORTH**
PUBLISHER **PEN AND SWORD**
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Take a walk through the woods with this insightful guide. Unlike many wildlife identification guides, this book reveals how life within the woods changes with the passing of each season. From farrow deer to finches, you'll discover the breadth of animals that forage on the forest floor and fly between the trees, along with the many species of plants, trees and fungi that form the forest. Each page is filled with handy tips and tricks on how to identify each species as the UK's woodland habitats change through the four seasons. The final chapter looks at the incredible conservation efforts that are restoring woodlands and what part you can play in encouraging nature. Though you might not find yourself packing this in-depth book along for a walk, it's got some great advice on spotting species that you can make a note of for your next wild adventure.

THE ASTRONAUT'S GUIDE TO LEAVING THE PLANET

EVERYTHING YOU NEED TO KNOW, FROM TRAINING TO RE-ENTRY

AUTHOR **TERRY VIRTS**
ILLUSTRATOR **ANDRÉS LOZANO**
PUBLISHER **WORKMAN PUBLISHING**
PRICE **£11.99 / $14.99**
RELEASE **OUT NOW**

Do you want to be an astronaut when you're older or have you just always wondered what it would be like out in space? This book, written by former NASA astronaut Terry Virts, provides real facts and first-hand experience. It covers historic space travel missions, the types of training involved, how astronauts live and work in space and top tips for future generations of astronauts. Much of this guide covers the general science and technology of space travel, but it also includes personal views, opinions and memories of being in space. Throughout it are 'Ask an Astronaut' pages covering fascinating answers from the astronaut himself. Some of these include what Virts' personal inspiration was, his favourite and least favourite school subjects, career highlights and the range of planets and other sights he's seen from space.

There's a combination of awe-inspiring photographs and creative illustrations that capture life in space with accuracy and vibrance. One of the most noteworthy features is the 'Astronaut Activity' pages, in which readers are invited to take part in simple activities that provide the feeling of preparing for space. These include experiencing free falling safely on park swings, physical exercise with walking tasks and investigating intricate technological items, as astronauts are often required to do while working on board the International Space Station. After absorbing the insight from this book, young readers will feel ready to explore the complex and exciting environments of space that await them.

HOW TO BUILD A RACING CAR

AN EDUCATIONAL AND PRACTICAL ENGINEERING GUIDE FOR KIDS

AUTHOR **FRAN SCOTT**
ILLUSTRATOR **PAUL BOSTON**
PUBLISHER **WALKER BOOKS**
PRICE **£14.99 (APPROX. $18.75)**
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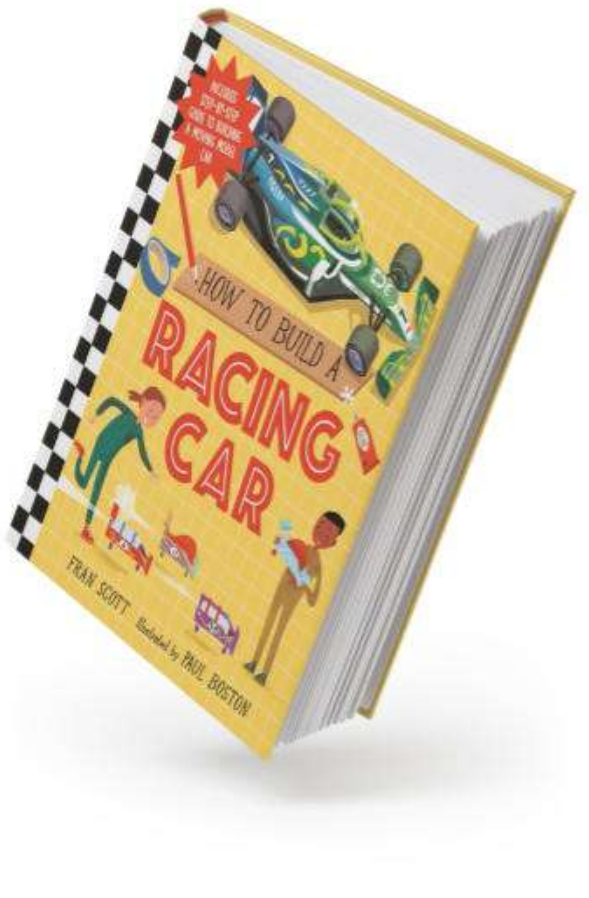
Welcome to the world of race car engineering. In this exciting and engaging book, you'll make your own racing car while discovering the techniques and people who've made this their career. In the Meet the Team section, you'll hear from seven people with different roles in the car-making process. The diverse group explain the most interesting parts of their jobs as an aerodynamicist, data engineer, strategist, mechanic and more. As the reader, you're invited to join the team and make a simplified version of a racing car using household objects.

With easy-to-follow instructions, encouragement and clear, colourful illustrations, young readers should have no problem creating their car, one step at a time. The homemade components include a strong yet light cardboard chassis, speedy bottle-top wheels and a personalised start gate. For the engine you can choose your own build, with options for a balloon core or a higher-tech bottle engine. By the end of this book, readers will be equipped with fun facts about the real world car-building industry and their own cool crafted car.



BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

5	1	9	7		2		3	
		2	3		1		9	6
6		7	4			1	5	2
	5	3	2				6	
8	6	4				2	7	
	2		6					9
3				2	4			7
1	4			9	7			
2			1					5

MEDIUM

9				4		1		
7	4	8				6		
	2				6		5	
	6				1			
5		4	6		8	9		1
			7			3		4
4				8	2		1	6
			1			2	8	
2		1	9	6				

HARD

				4	8			1
		3					2	
		4		7		6		5
4			8				6	
		9	2				5	
						7		
	3	2						
				6		4		2
1		5	7			9	8	

Word search

Find the following words

CATS
DOGS
SPACESHIP
MEDIEVAL
FOG
PLANT
BRAKE
CRASH
MARINE
MONEY
HAWKING
MEMORY

S	T	A	C	L	K	O	T	M	A	L	P	U	I	M
Y	F	G	M	E	D	I	E	U	A	R	M	E	H	E
V	M	O	N	E	Y	S	H	A	R	C	A	T	A	S
P	Q	A	C	O	L	B	R	A	X	E	N	I	W	K
J	L	F	D	E	C	R	A	S	H	S	T	U	K	N
S	P	A	G	E	S	H	I	D	Y	O	B	A	I	F
Y	U	E	N	M	E	D	T	H	I	E	X	D	N	K
R	O	S	G	T	B	E	N	S	Q	K	U	O	G	L
O	Z	O	C	R	N	A	G	I	N	A	L	G	P	A
M	F	I	P	I	O	M	E	M	Q	R	Y	S	I	V
E	J	E	R	P	A	L	N	T	F	B	O	G	M	E
M	R	A	N	I	M	E	N	O	R	Y	M	A	R	I
O	M	U	D	O	C	S	T	A	G	K	L	P	E	D
R	A	S	P	A	C	E	S	H	I	P	O	L	K	E
R	E	B	O	N	T	E	L	Z	U	N	T	I	P	M

What is it?

Hint:

Not just a plane old fan

A

Spot the difference

See if you can find all six changes between the images below

QUICKFIRE QUESTIONS

Q1 According to the Apollo astronauts, what does Moon dust smell like?

- Burnt gunpowder
- Blue cheese
- Petrol fumes
- The seaside

Q2 The word 'muscle' comes from the Latin term for:

- Strong fibres
- Little mouse
- Curled cat
- Flex and stretch

Q3 Approximately how much skin do you lose every year?

- 4.0 grams
- 40 grams
- 400 grams
- 4.0 kilograms

Q4 Comets are mostly made of ice, dust and which gas?

- Halogen
- Phosgene
- Carbon dioxide
- Oxygen

Q5 What could the electricity in your brain power?

- A personal computer
- A house for a year
- A family car
- A light bulb

Q6 What year was the first plastic invented?

- 1907
- 1927
- 1957
- 1997

Answers

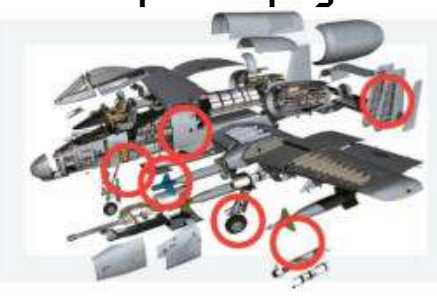
Find the solutions to last issue's puzzle pages

Q1 ASIA
Q2 0
Q3 115,000
Q4 JUPITER
Q5 TOMATO KETCHUP
Q6 SNEEZE

What is it?

MARKER PEN

Spot the difference



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HOW TO...

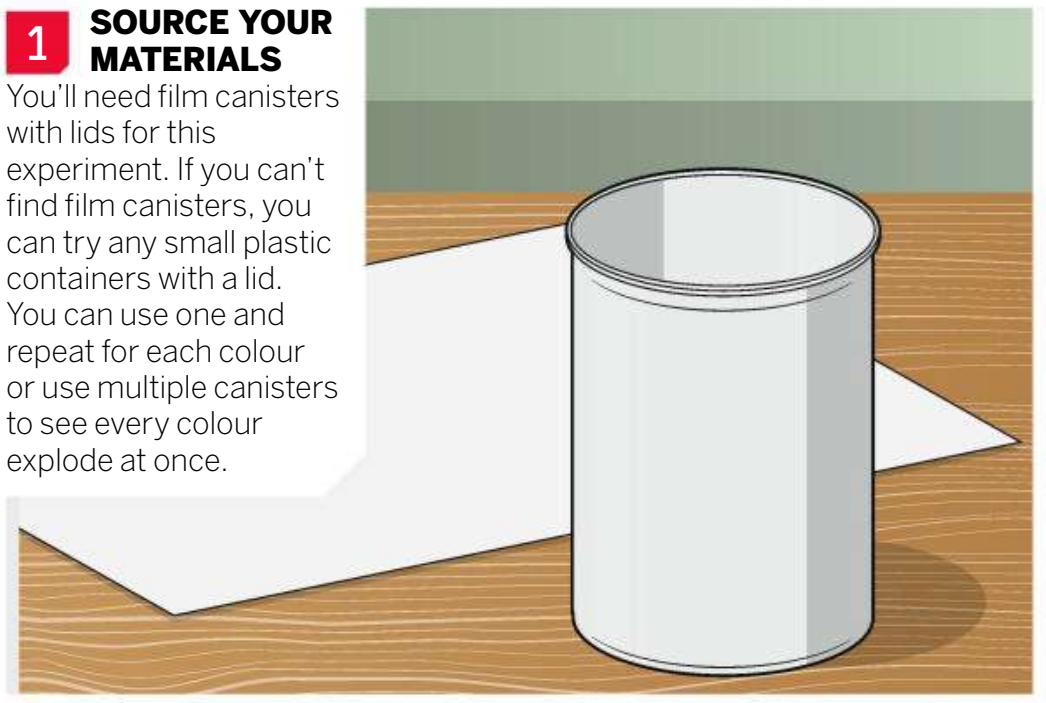
Practical projects to try at home

MAKE EXPLODING PAINT BOMBS

This chemical reaction creates a unique piece of art

KIT LIST

- Film canisters
- Alka-Seltzer tablets
- Water-based paint
- Paper (ideally watercolour paper)

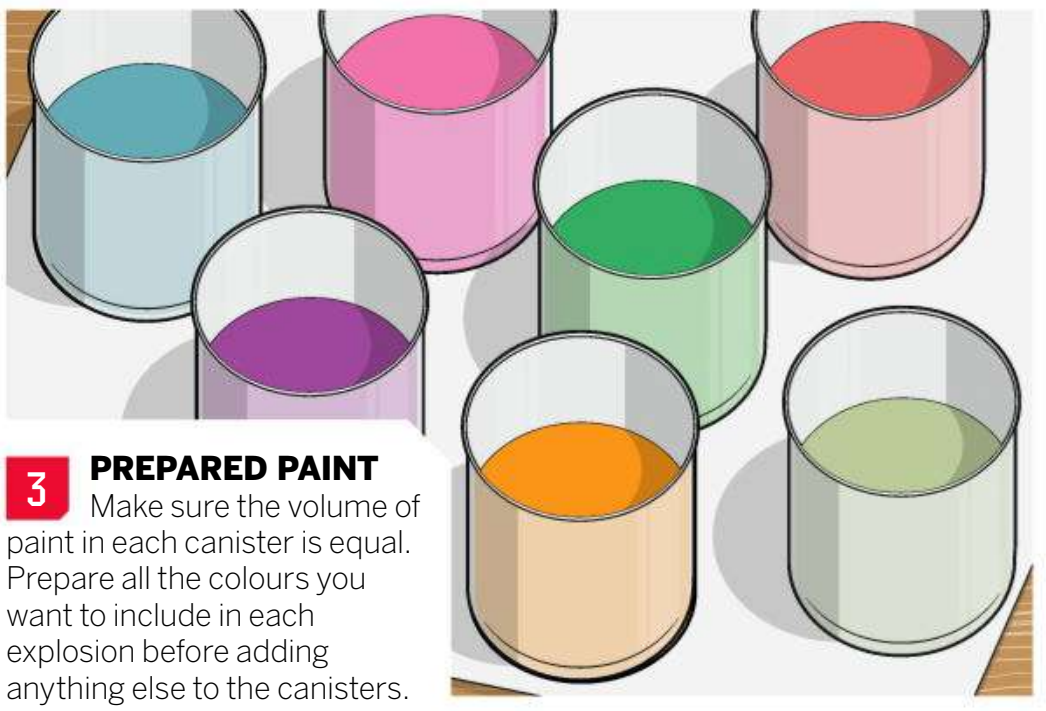


1 SOURCE YOUR MATERIALS

You'll need film canisters with lids for this experiment. If you can't find film canisters, you can try any small plastic containers with a lid. You can use one and repeat for each colour or use multiple canisters to see every colour explode at once.

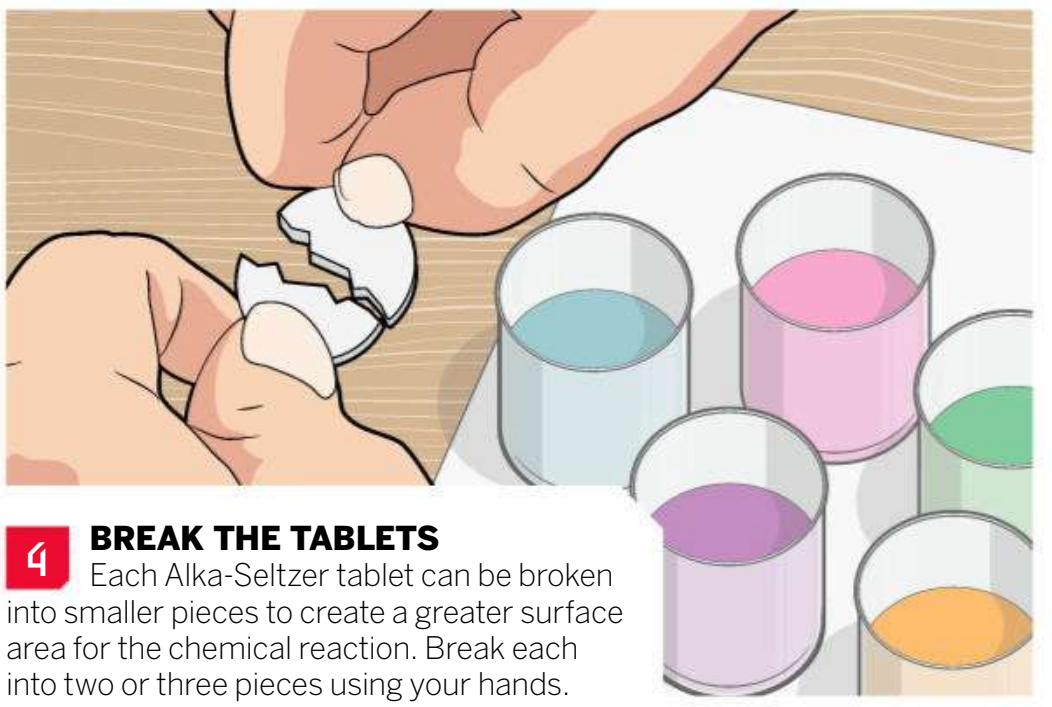
2 LOAD THE CANISTERS

Pour a different colour of paint into each of the canisters. You don't need much paint – the paint line should measure about one centimetre from the bottom of the canister.



3 PREPARED PAINT

Make sure the volume of paint in each canister is equal. Prepare all the colours you want to include in each explosion before adding anything else to the canisters.



4 BREAK THE TABLETS

Each Alka-Seltzer tablet can be broken into smaller pieces to create a greater surface area for the chemical reaction. Break each into two or three pieces using your hands.

5 ALKA-SELTZER ALLOCATION

Allocate one small piece of Alka-Seltzer tablet to each canister, but don't place it into the paint yet. Make sure there is at least one piece next to each canister.

6 QUICK DROP

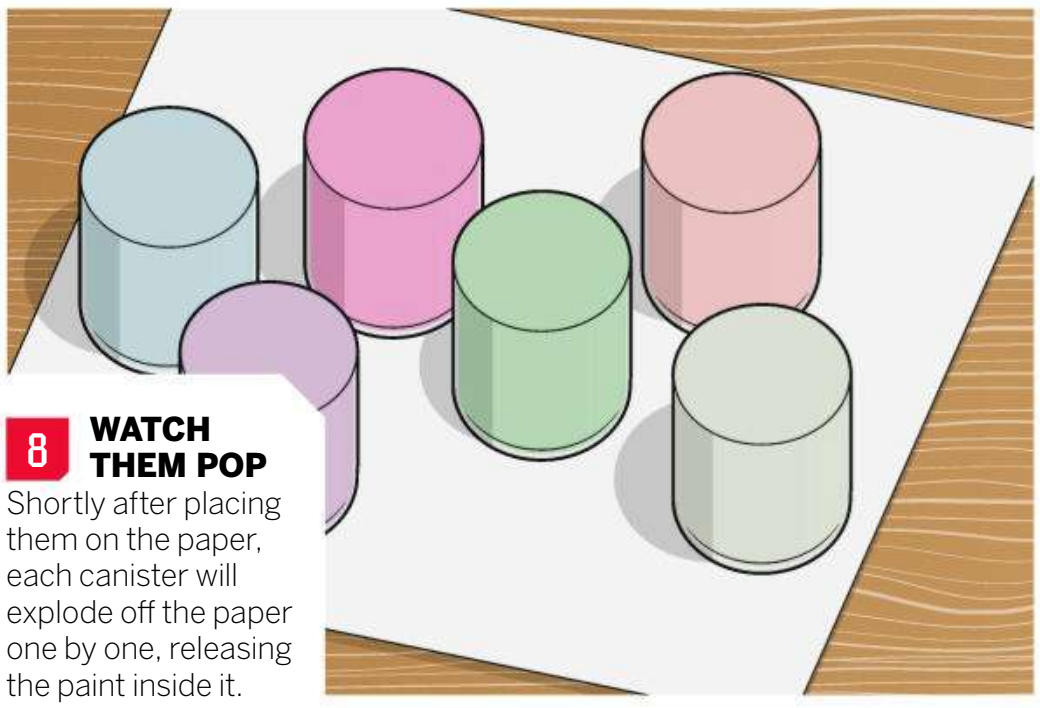
When you're ready to start the reaction, place the tablets into the paint and quickly put the lid on each one. Make sure you have found a suitable place to carry out this experiment first, such as in the garden, as the paint can get messy.

DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you

7 SHAKE THINGS UP

Firmly and in quick succession, shake each canister and place them upside down on the paper – with the lid facing downwards.



8 WATCH THEM POP

Shortly after placing them on the paper, each canister will explode off the paper one by one, releasing the paint inside it.

9 UNIQUE CREATION

When each canister has finished exploding, look at the artwork that's left behind by the paint explosions. You can reuse the canisters to add more colour to your paper until you are happy with the result.

SUMMARY

This artwork is created by an explosive chemical reaction taking place in each of the canisters. When you shake them, the citric acid and baking soda in the tablets come into contact with the water in the paint and react. The chemical reaction produces carbon dioxide, which is trapped inside the enclosed canister. This is an acid-base reaction, with the baking soda as the base. The two can't mix until they're combined with water.

As the reaction continues and carbon dioxide gas builds up, the pressure increases until the contents can't be contained any longer. The paint is released from the container in small explosions, shooting the canisters into the air and splattering paint over your previously blank paper. It's almost impossible to completely control this experiment, so it's best not to try this experiment indoors.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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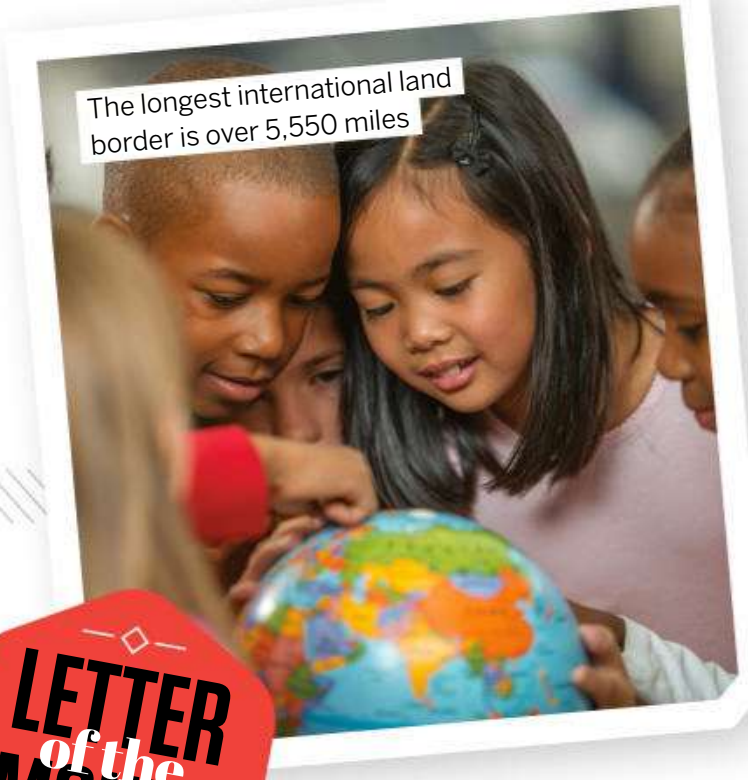
INBOX

Speak your mind

A NOTE TO THE EDITOR

Dear **HIW**,
I'm a Grade Nine student from British Columbia, Canada. I've been a keen reader of **How It Works** since I first discovered it on the teenage shelf in the library. Over the years, I've followed your magazine from the library to subscribing to it on my Apple device. It has been my best teacher and friend. I love geography, and thanks to your magazine I was able to achieve third place in the Canadian geography competition. I also love science, and with the inspiration from your magazine, I started my own podcast channel to explain the latest scientific information to children.

I'm writing to bring to your attention an error I noticed on page 71 of Volume 12 of the **HIW Annual**. The map used doesn't accurately reflect the actual borders of the countries, leading to some misrepresentation of their size and shape. When my mother used this map to explain the different directions of a hurricane to my younger brother, I noticed that the images might mislead young children. Thank you for continuously providing me with a vast knowledge repository on the world of human and scientific knowledge. Thank you for opening the door to my childhood, and for being such a great inspiration.
Eric



LETTER of the MONTH

It's fantastic to hear all about your journey in science and interest in geography. It sounds like you're very talented, and we hope you keep up the great work. We would love to listen to your podcast, and it sounds like sharing your passion will benefit many young minds. Thank you for letting us know of an inaccuracy. We'll look into this to ensure that the most accurate maps are used. We welcome any letters with reader's thoughts and areas for improvement, and we wish you all the best in your future projects.

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

WONDERFULLY WIRED BRAINS

An informative and inclusive guide to the brain and neurodiversity that will inspire and inform all children

COUNTING STEPS

Dear **HIW**,
How does my fitness app on my phone tell me how many steps I've taken in one day, especially if it's in my bag or my coat pocket?
Amy Webster

Our devices can collect data on our movements using accelerometers, gyroscopes and GPS trackers. Accelerometers monitor the acceleration of movement along three different axes. The collected data helps determine whether it's travelling with a person who is walking, jumping or staying still. Gyroscopes use gravity to record the orientation of the device. This makes the data more accurate as the angle of movement and direction can be better recorded. Finally, GPS data pinpoints the exact distance that's covered for each step count. When the device is kept in a bag, it still covers the same distance and will be exposed to similar movements, but it can move more inside the bag and create a less accurate step count. For the best results, keep your phone close to your body, such as in your pocket.

SHELLED PISTACHIOS

Dear **HIW**,
Do pistachios naturally have open shells, or does something need to be done to them before they're packaged?
Sohini Naeem

The split in a pistachio shell is natural. When they're ripe enough, their hard shell cracks slightly, indicating that they're ready for harvesting. This doesn't happen with all pistachios, as only 70 to 90 per cent develop splits in their shells. Pistachios grow in bunches, similar in shape to grapes, and each will fall to the ground individually once their shells have split. The smaller pistachios usually don't form a crack in the shell, but industrial shell-splitting machines can be used to expose them.

Iran is one of the world's biggest pistachio producers

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Vines, grasses and trees benefit from regular trimming

CUTTING QUESTION

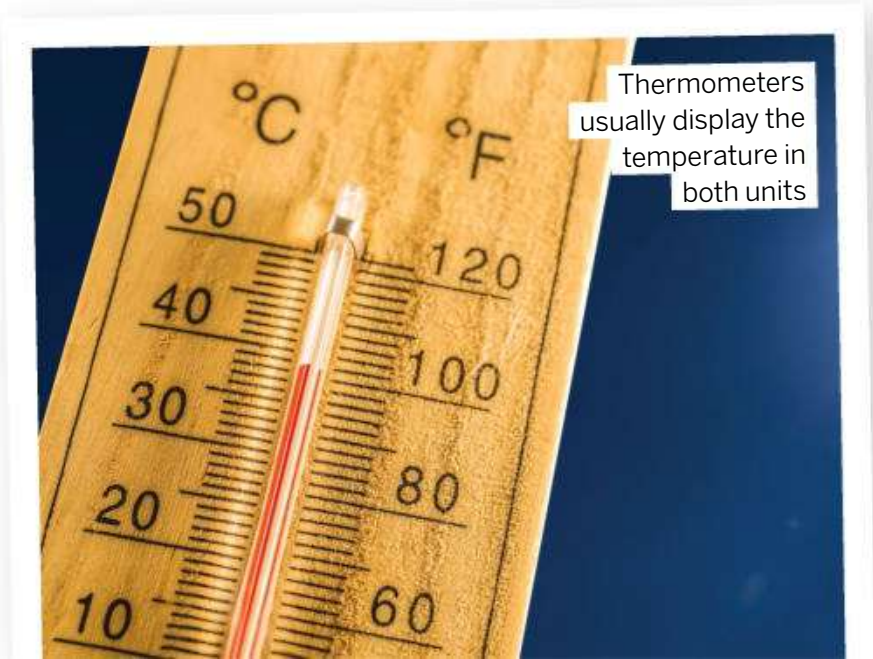
Dear **HIW**,
Do plants grow faster after you cut them? I've noticed that one plant which I've cut is catching up with one I did not.
Jennifer Doyle

Trimming your plants can help stimulate growth, as long as it's done correctly. Dispersed along the length of plants are regions that store growth hormones. When the cells near these areas are damaged – like when they're cut by scissors – these hormones react by repairing and growing the plant more rapidly. You should cut just above leaves or leaf buds to stimulate this response and avoid causing irreparable damage to your plant.

HOTTOPIC

Dear **HIW**,
Why are there two different temperature measurements for Celsius and Fahrenheit?
Billy Tyman

In most countries, Celsius is used to measure temperature, while countries such as the US, Myanmar and Liberia refer to temperature in Fahrenheit. The lesser used Fahrenheit scale was actually the first to exist, but was replaced in most countries by the Celsius scale. The two were invented by different scientists. The Fahrenheit scale was invented by German physicist Daniel Gabriel Fahrenheit in 1724, with 32 degrees for the freezing point of water and 212 degrees for its boiling point. Separately, the Celsius scale was invented in 1742 by Swedish astronomer Anders Celsius: 100 degrees for the freezing point of water and 0 degrees for the boiling point before the scales were swapped to make 100 degrees the boiling point.



Thermometers usually display the temperature in both units

WE ASKED YOU

This month on social media, we asked you: Are you a cat or dog person?

KIRA HALL

Cat person. I've grown up with them and mine show as much affection as dogs

HANNAH MARSH

Dogs because they're so loyal and friendly

MAXWELL BARRETT

Cats seem much more intelligent

DAVE F

Cat person, they're so playful and have a world of their own

ISABELLA ROWLANDSON

I'm a dog person. I just think they're cuter

JOSHUA CRAIG

Dogs because you can never be lonely with one

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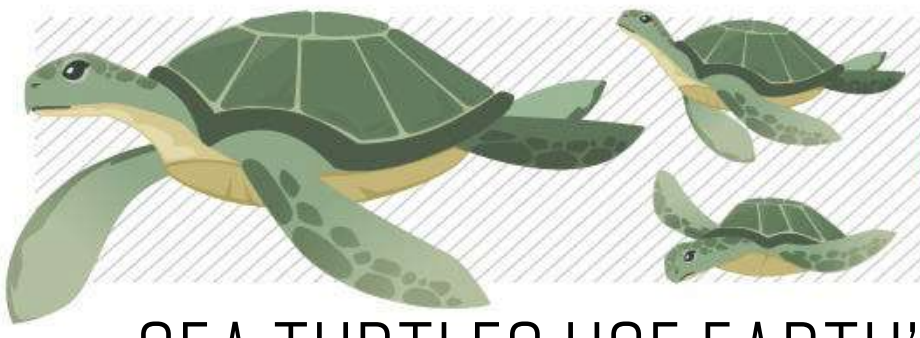
FAST FACTS

Amazing trivia that will blow your mind

33.6 BILLION LIGHT YEARS

JADES-GS-Z13-0 is the oldest and farthest known galaxy from Earth



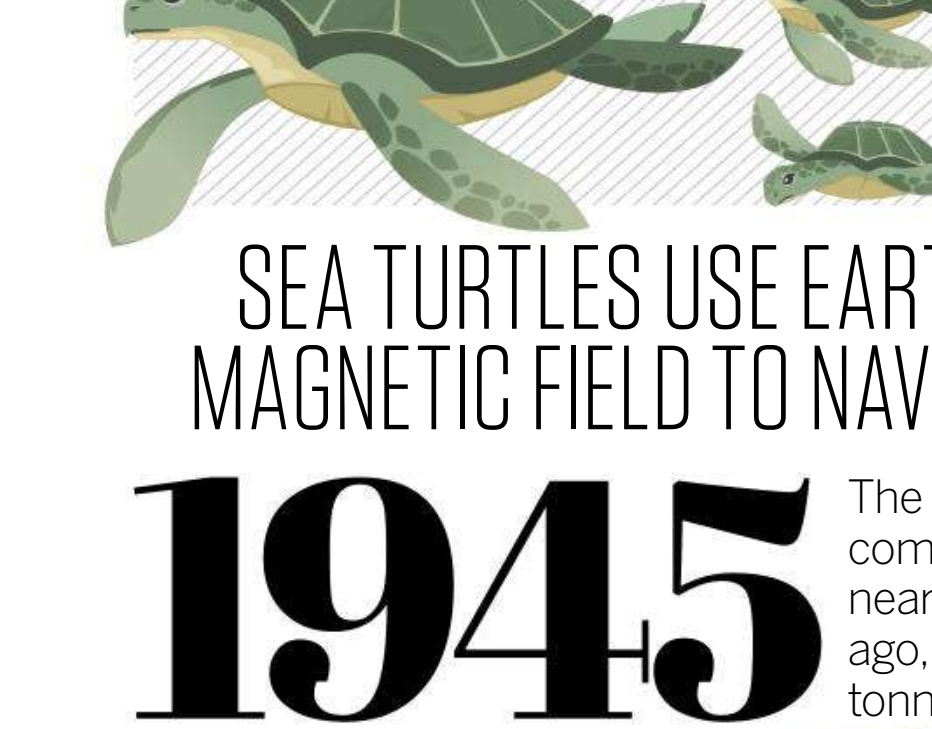
SEA TURTLES USE EARTH'S MAGNETIC FIELD TO NAVIGATE

1945

The world's first computer, built nearly 80 years ago, weighed 27 tonnes

165 TONNES

The blue whale is the heaviest animal that's ever lived



100 MILLION

A single teaspoon of soil contains millions of bacteria

25%

A quarter of the oxygen we breathe goes to our brain

10 MILLION

Our eyes can differentiate between a huge range of colours

66 kilograms

The world's largest gold nugget, found in Australia in 1869, would be worth nearly £3.5 million ($4.35 million) today

15.1 METRES

The dinosaur *Mamenchisaurus sinocanadorum* had a neck longer than a bus

Hurricanes cannot form at the equator

ASTRONAUTS SPEND MOST OF THEIR TIME ON EARTH SUPPORTING MISSIONS

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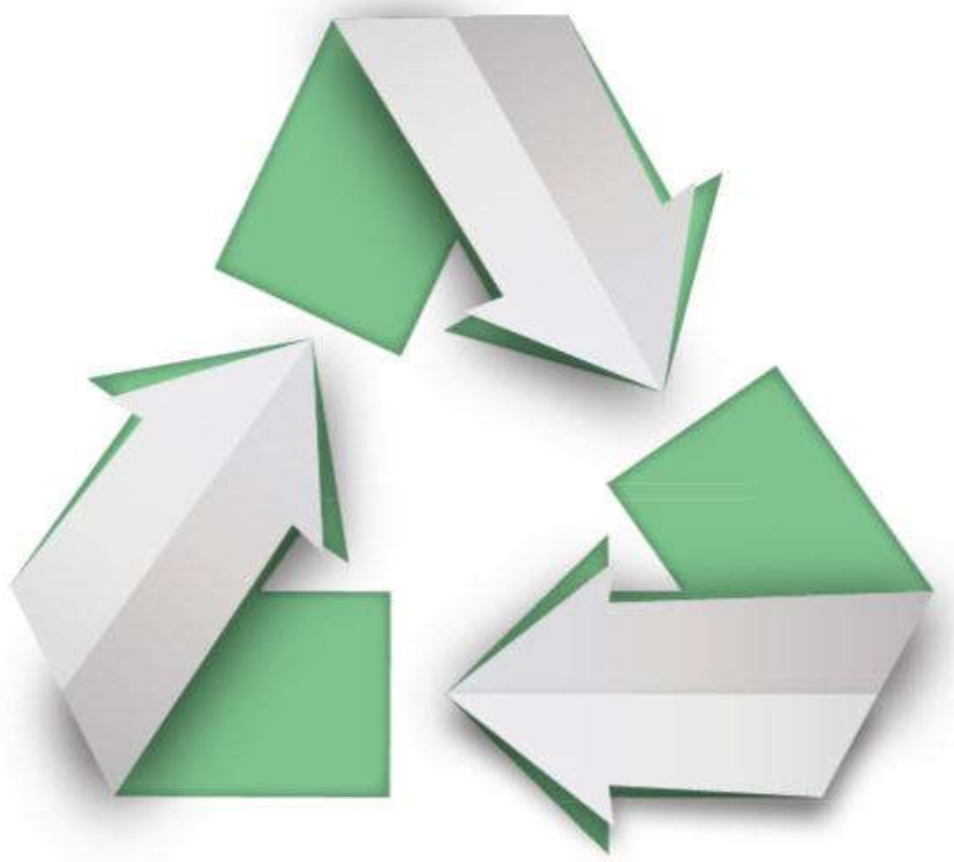

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Europe: EU27 + Norway, Switzerland and the UK.

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